Economic Analysis of Recapturing and Recycling Irrigation Techniques on Horticulture Nurseries

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ABSTRACT

The horticulture industry is facing limited water resources and public pressure to reduce non-point source pollution. In some circumstances, recapturing and recycling of irrigation water in horticultural nurseries can generate significant savings relative to the costs of alternative water sources and potentially reduce non-point source pollution. However, obtaining these savings may also incur substantial risk and capital cost outlays. Disease risk may increase in nurseries that implement recapturing and recycling if recycled water is not properly treated. These added costs must be compared with costs of alternative sources of water, such as municipal or well water. This study employed partial budgeting to compare irrigation water being extended or supplemented through recapturing and recycling against the most feasible alternative. On-site visits were conducted to obtain information for partial budgets and to clarify the reasoning of nurseries choosing to recycle irrigation water. The partial budgets were supplemented with sensitivity analysis with regard to the extraction cost of water and opportunity cost of land used for recapture of water. Six of eight nurseries obtained water from recapturing and recycling at a lower cost compared to a feasible alternative source. The regrading of land for maximum recapture, opportunity cost of land dedicated to a recapture pond, and the cost of municipal water were parameters that were critical to the irrigation choice. Sensitivity analysis indicated that water price and land cost had little effect on the least cost option. Irrigation recycling could be incentivized to motivate further water conservation within the horticulture industry.

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Chapter 1 Introduction

Fresh water is becoming scarce due to increasing demands from the public for household, commercial, and environmental uses. Consumers will be adversely affected as scarcity becomes more acute and costs rise. As fresh water supplies become more limited, innovative technologies and policies must be developed to address scarcity and manage business risk. Water recycling techniques offer one solution to this problem by extending the availability and the conservation of water. This project documents how selected case studies of nurseries have responded to water scarcity by recycling irrigation water and the estimated effects of recapturing and recycling on the operation's net returns.

Recapturing and recycling of irrigation water in horticulture was first undertaken at Monrovia Nursery in Cairo, California. The business did not want incur costs for runoff which could be reused onsite and in the 1970's, Monrovia became the first nursery to use captured, treated, and recycled water for portions of irrigation in its nursery (Encyclopedia of Business, 2014). Many container nurseries across the U.S., particularly those in more arid or drought-prone areas, have implemented recapturing and recycling technology.

Changing rainfall patterns and fear of tightened governmental water regulations have led container nurseries to implement recapturing and recycling techniques as a partial or complete water source. The area of focus in this study is the mid-Atlantic region of the United States, with emphasis on the states of Maryland, Pennsylvania, and Virginia. The climate of these states is such that rainfall is a major source of water for horticultural production although supplemental irrigation is often required. The differing climates can be shown by the average rainfall from 1914 to 2014 in California which is 22.16 inches annually, which is about half of the average rainfall in Virginia, 44.10 inches, over the same time period (NOAA, 2015b, 2015d). Likewise, Pennsylvania and Maryland have annual rainfall of 42.30 and 43.09 inches respectively on average between 1914 and 2014 (NOAA, 2015a, 2015c). Thus, the mid-Atlantic region has a larger opportunity to capture a bigger portion of water from rainfall runoff than states such as California. Primary sources of irrigation water for nurseries in the mid-Atlantic region are municipal water, well water, surface water, rainfall, and recapture. Municipal water is very reliable but can be expensive to meter and costly to access. Well water is a relatively cheap alternative, however access to property above an aquifer with adequate recharge is crucial and initial outlays for well drilling may be expensive. Rainwater is the most variable of all sources, but is also the cheapest in terms of both fixed and variable cost, assuming the land is properly suited to recapture. Combining these water sources with recapturing and recycling allows for stable costs and a reliable source of water when needed. However, this practice comes with hazards; for example, recapturing water used as an irrigation source may increase the risk of pathogen infection of irrigated plants if water is not thoroughly treated. Thus, the security of clean water is a prime objective of nearly every nursery.

Nurseries may potentially face higher water costs as a result of climate changes and more stringent regulations. The Clean Water Act or 1972 was initially enacted in an attempt to regulate wastewater discharge (Environmental Protection Agency, 2015). As recycling programs were initiated throughout the state, the reuse of recycled water became more common (Schulte, 2011). Schulte argues that recycling will reduce water pollution, support healthy ecosystems, minimize energy requirements and costs, and augment the available water supply. The latter two effects, minimizing cost and increasing water supply, are the most significant to the net returns of horticultural nurseries and other farms. Cutting costs and finding cheaper sources of water could be the difference between a successful, thriving business and declaring bankruptcy in areas where clean water is becoming scarcer.

Due to the finite nature of fresh water in the future, recapturing may be a more viable economic option than irrigating with municipal water and well water. The recapture and recycling of water would allow a nursery to be self-sufficient rather than to rely on other water sources that may experience price shocks; if the land is adequate for recapture. Recapture is also versatile and can work as a complement to any existing water source. The implementation and use of recaptured water for irrigation may come with significant costs. Recapturing used irrigation water for recycling can possibly increase the risk of pathogen contamination throughout the nursery operation. There are possible ways to mitigate pathogen risks. These pathogens can live in recycled water, thus causing re-infection of plants each time the water is recycled through the irrigation system. There are best management practices (BMPs) that attempt to mitigate possible risk, such as water treatment methods or increasing the water residence time (C. Hong, 2014), which may be costly to implement. BMPs include options that help control pollutants such as "…activities, prohibition of practices, maintenance procedures, or other management practices" (Title 40, 2014). Recycling requires that the land be contoured and an area be set aside for the pond to recapture water, which may replace production of profitable plants. Therefore, nurseries face the choice of regrading the land to recapture and recycle water, while implementing pathogen mitigation procedures; or of using an alternate source of water that does not require pathogen mitigation. The choices of water source are contingent upon having land located in an area where access to differing options is present.

An analysis of recycling costs in comparison to other water sources will assist the nursery's decision to recycle. This analysis is designed to provide information on the lowest cost of collecting water and irrigating plants. This information is of interest to growers and farmers who have questions about the cost efficiency of their current water irrigation methods. Policy analysts and decision makers, especially in water conservation, are interested in the implications of water recycling and its costs relative to other alternatives. Recycling of irrigation water is viewed as a potential conservation practice to assist in meeting water quantity protection goals. The Chesapeake Bay Program looks to curb agricultural practices that could damage surface water bodies, such as runoff from agricultural operations (Chesapeake Bay Program, 2012). Businesses that provide services for recycling can learn about the feasibility of incorporating new customer bases to their existing clientele, whereas some industries that exploit conventional water services might see more profitable alternatives to their current technologies.

The objectives of this project are 1) to estimate the cost of a recapturing and recycling program for a horticulture operation; 2) to compare such costs against the next best water source alternative; and 3) to conduct sensitivity analysis to determine how changes in the opportunity cost of land used for recapture of water affect recycling costs compared with competing water uses.

In order to meet these objectives, case studies using partial budgets are developed to analyze nurseries of differing sizes and locations. Partial budget analysis is used to evaluate costs and benefits of recycling versus developing alternate water sources and is applied to nursery case studies. The nursery case studies are compiled through on-site visits to each operation to document the costs coupled with recapturing and recycling of water as well as factors influencing decision making. In-person visits offered an examination of the costs associated with regrading the land, recapture ponds, and pathogen mitigation techniques. For costs that nurseries could not provide, industry cost sources were consulted. The partial budgets compared the costs associated with recapturing and recycling water to the next best water source alternative, and these costs are elaborated upon in later sections.

The following sections describe steps relating to the composition of the partial budgets. The first step is focused on developing realistic estimates for nursery costs to anchor the partial budget firmly in consistent prices. Second, an alternative option is defined for each nursery to use as a comparison in the partial budget analysis. Third, the sensitivity of the analysis to varying land opportunity cost. Finally, conclusions from the studies are drawn to map the decision making process for the nurseries that were visited and sum up the overall results of the individual partial budgets.

Partial budget analysis is a versatile tool that can be used in a range of applications, though it is especially well suited for agricultural decision-making. Similar studies comparable to partial budgets were examined to provide guidance, such as horticultural enterprise costs (SAAESD, 1943-2015), and costs of alternative agricultural water systems (Brennan et al., 2008). The study will use the partial budget to analyze the choice of different water sources, including recapturing and recycling, for specific horticulture container nurseries. The individual local market and production practices of each nursery differ greatly though each produces similar products that result in differing costs from operation to operation. The nurseries are unique. While all may produce similar products, the location and physical area in which these products are produced can be drastically different, leading to different costs. Through this research, it is hoped that a better understanding can be gained of cost and decision making as it pertains to water and land use of ornamental horticultural nurseries in the mid-Atlantic region. The hypothesis states that nurseries that recycle do so because recycling is a lower cost option than alternatives. The paper is divided into a literature review, methodology, results, analysis, discussion, and conclusion.

Chapter 2 Literature Review

Ornamental crop production hinges on the ability to regularly access a given quantity of quality water to produce ornamental plants including bedding plants, trees, and shrubs. If the plants experience a water shortage, growth and sales stagnate and the company's bottom line suffers. The ability to get that water is linked to the location where the nursery is situated. Therefore, nursery location with regard to water access is crucial to the survivability of the operation. In *So You Want to Start a Nursery* Avent (2003) summarizes the various aspects of planning, purchasing, and operating a nursery. He discusses an assortment of topics from the type of nursery to run, which plants to grow, employee and insurance needs, and outlines the basic foundation of how to run a nursery. Avent (2003) stresses the importance of land selection:

> "…the land you choose has an impact on virtually everything you do, from the plants you can grow to the customers you will have, the labor you can hire, the irrigation you can use, the winter protection you will need, and the cost of producing your plants" (p. 37).

The placement of a nursery has a large effect on what the nursery can produce and how it can produce it. The site location dictates its access to usable water. As Avent (2003) indicates:

> "…growing plants successfully depends on one factor above all others and that is an adequate water supply […] whether that supply is in the form of ponds, wells, or streams" (p. 42-43).

Location with regard to water access is a key factor; however, an equally important factor is the quantity and quality of that water (Rolfe, Yiasoumi, Keskula, & NSW

Agriculture, 2000). The lack of accessible water could force recycling for irrigation purposes in response to future water shortages.

Australia has been the leader in many recycling innovations and research, stimulated largely by its arid climate and extended periods of drought. A study done by Gyles (2003) estimated savings in terms of water management. He outlines three technical inefficiencies within an irrigation system: spillovers, seepage, and evaporation. These inefficiencies present obstacles to effective recapture and recharge. Spillovers occur when water escapes the production area, such as run-off entering a nearby river due to excess rain causing flooding in the area. Seepage occurs as water is lost from the surface and is no longer accessible by plants. The final inefficiency is evapotranspiration, which accounts for massive losses of irrigation water. Evapotranspiration is characterized by evaporation from water bodies, and transpiration from plants, and must be considered in the way that water is stored in a nursery (USGS, 2014). Many growers face the difficulty of implementing a cost effective technique to decrease the evaporation rate in a water supply due to these inefficiencies (Gyles, 2003). Horticulturalists and farmers all over the world are looking for cost-efficient ways to retain water to prevent or prepare for future shortages. Planning for such problems will require large capital investments.

The science community has been grappling with this question of water scarcity for some time. For instance, Seckler et al. (1999) state that "…water scarcity has become the single greatest threat to food security, human health, and natural ecosystems" (p. 29). Since 1999, the news regarding water supplies in certain areas of the world has become more pessimistic. As the world struggles with water scarcity, growers may find fewer markets for their commodities as customers may have less water for plant upkeep and less available water resources for production (Seckler, Barker, & Amarasinghe, 1999).

A possible solution comes from Fereres, Goldhamer, and Parsons (2003) who agree with the notion that water supplies are increasingly strained. They acknowledge that other sources and industries are diverting larger amounts of water from the agriculture sector, just as the global population is expanding. Sustainable water management is essential to coping with the continued pressures of a growing world. The authors indicate that future advances will be found in affordable monitoring systems that allow farms to only apply water when necessary to facilitate conservation and savings (Fereres, Goldhamer, & Parsons, 2003).

Meyer (2008) supports the argument of Fereres, Goldhamer, and Parsons (2003). His study indicates that "[w]orldwide, 70% of water withdrawn for human use is used for agriculture…"(p. 449) (Meyer, 2008). Meyer's proposed options are similar to those of Fereres, Goldhamer and Parsons (2003), as he argues that efficiency is paramount in overcoming the problem. He takes it a step further and calls for more local crop production from the surrounding areas to ameliorate future water demands due to increasing energy costs associated with transportation.

Areas in the western United States are already experiencing severe water shortages. A study done by the Cooperative Institute for Research in Environmental Sciences (CIRES) analyzed the capacity of watersheds to supply human water needs through the use of natural water sources in the region. The study found that cities and municipalities around the country may face reduced water supplies. This research suggests that the need for recycling could be more acute (Rodda, 2014b). In addition, if those regions do have to limit their water uptake, ornamental horticulture sales could suffer as residents without access to adequate water supplies at home may not be able to buy and sustain ornamental plants.

A recent article states that nearly 30% of the United States could face water shortages over the next decade (Moulden, 2014). The author summarizes the steps that certain localities are taking to respond to water shortages highlighting technology that converts wastewater to drinking water. The state of Delaware has been using reclaimed water to irrigate cropland for several decades (Moulden, 2014). These types of projects show where future techniques and policies for agricultural irrigation may be moving forward.

Large scale water recycling techniques can be used to conserve water and cut costs. Researchers at Texas A&M have been studying the recycling capacity of a plot of land with limited rainfall. Texas A&M's University Agrilife extension agents have developed a rainfall calculator that discerns how much rainfall could be captured and turned into usable water. Rodda (2014) interviewed the lead researcher, John Smith, who explains that rainwater is free of heavy metals until reaching the ground and does not possess an abundance of hard minerals or salts (Rodda, 2014a). Rainwater recycling is an alternative that could reinvigorate irrigation of a horticultural farming area. However, problems with upfront costs may arise in the regrading of land to get the maximum amount of rainfall into containment areas or vessels while accounting for losses from rain percolating to groundwater.

There are a variety of water source options for irrigation. Bores, spearpoints, and wells tap underground water, which is commonly of high quality, and could be crucial for irrigation needs. All three options require large capital outlays to gain access to the water resources and extract the water (Rolfe et al., 2000). Another option is the farm dam and pond system. These are examples of a permanent watercourse that "…is generally the cheapest source of supply, as well as the preferred option" (Rolfe et al., 2000). A dam or pond storage can be separately supplied by rainwater/runoff or supplemented from wells, springs, and other sources. Another source of water can be the municipality or the locality's public water system. This water source offers an effective way to access water without interruption; however, there are relatively large initial capital investments for a nursery related to the installation of water meters, usage tariffs, and water availability costs. These costs are not insignificant and can become a barrier to implementation.[1]

Treating and screening incoming water is important for efficient nursery management. Poor water quality may be caused by using water from alternative sources if water is not properly treated. Causes of poor quality include contamination by physical materials, chemicals, and pathogens (Rolfe et al., 2000). Pathogens are biotic organisms that can be transmitted and cause disease in plants (Science Daily, 2015) and are of most interest in this study because the incidence of pathogens may increase with recycling. Recycling of water, can also have other unwanted off-site effects such as nutrient pollution, excess clogging of filters and irrigation pipes, as well as biological growths (Rolfe et al., 2000). As water is recycled through the irrigation system, pathogens can multiply if not properly treated.

If waterborne pathogens are present, there are possible disease consequences for the nursery (C. X. Hong & Moorman, 2005). Untreated recycled water will have a higher concentration of pathogens than water that is used just once, as "…[s]ome important soil

[1] See Case Studies in Appendix A

borne pathogenic fungi can live freely in water, such as *Pythium, Phytophthora* and *Olpidium* sp. These fungi have zoospores that swim and are attracted to plant roots" (Rolfe et al., 2000). Zoospores are asexual spores that allow the pathogen to reproduce (Biology Online, 2009). The zoospore's asexual nature and flagellum allows for easy spreading over a large area. There is a variety of best management practices that can help control such pathogens that will be discussed later in the paper.

Waterborne pathogens are of critical consequence in nursery activities and can enter irrigation water through a variety of sources. Hong and Moorman (2005) analyze various avenues by which pathogens could enter water via soil, plant debris, or other non-treated surfaces. Recapturing water increases the chance that runoff water will contact some material containing pathogens. These pathogens, in particular *Phytophthora* and *Pythium,* can negatively impact horticultural nursery products. *Phytophthora* can be a soil or plant borne pathogen that causes root rot. *Phytophthora* symptoms include stunted growth, dead feeder roots, and eventually death of the plant (Moorman, 2015a). *Pythium* is a fungus that could also causes root rot and can be transmitted by field soil, sand, pond, and/or stream water. The symptoms of *Pythium*, like those of *Phytophthora*, are stunted growth, yellowing or browning of the plant, and wilting during the day (Moorman, 2015b). Pathogen risks such as these make it crucial to prevent problems in recycling nurseries (C. X. Hong & Moorman, 2005).

The horticultural industry is especially vulnerable to unintended effects of recycling water. For example, certain waterborne diseases can be propagated within recycling water and may be fatal to plants. Left untreated, these disease organisms may increase in numbers within the recycling system and infect more plants. Fortunately, there are precautions that can be taken for disease management when recycling water. However, these precautions do take extra time and resources (C. X. Hong & Moorman, 2005) .

There are many BMPs for nurseries to combat pathogens. BMPs are an "…approach to pollution control in the USA that is based on adopting methods that have been determined to be the most effective, practical means of preventing or reducing water pollution from non-point sources" (Park & Allaby, 2013). BMPs with regard to pathogens would be the best available technology to prevent or reduce water contamination. The BMPs are a series of options of varying cost that the grower can use to mitigate problems.

Additionally, there are a variety of BMPs by which a nursery could conserve water quantity, improve or retain quality, or combat diseases. Each of these techniques attempts to combat the spread of diseases and debris through the irrigation system. Conservation of water is also important for many nurseries as water availability could be an issue based upon location or capital investments. There are many ways for a nursery to combat the various waterborne threats that occur in recaptured water including, but not limited to, some combination of filtration, chemical treatments, ozone, and ultraviolet light (Fischer, 2013). Filtration is one of the most widely used techniques.

Filtration devices combat problems that could arise throughout the recapture process. Of the respondents to the Cultice (2013) survey, twenty-seven of the forty-two recycling nurseries indicated that they use sand filters. Water filtration is typically a preliminary step for recaptured water, and the first line of defense in purification. There is small screen/mesh filtration, media filtration, and membrane filtration that can be used to cleanse the water. The screen/mesh filters are outfitted to block inorganic and/or organic particulates. The media filtration is also equipped to block inorganic and organic particulates. To eliminate dissolved inorganic and organic particles, the use of a membrane filter is the best option. The finest setting of the membrane filtration involves reverse osmosis and can be effective at ridding water of all dissolved particulates (Fischer, 2013).

Chlorine is a chemical commonly used for water treatment, water sanitation, and elimination of pathogens. Of the respondents to the Cultice survey (2013), thirty of the forty-four recycling nurseries indicated that they use chlorine or another disinfectant. The chlorine is most commonly added to the water through a gas chlorination system, but can also be added as a liquid (after being diluted) to the water source or storage. Chlorine rids the water of pathogens by oxidizing their cellular walls (EPA, 1999a). One problem with the use of chlorine is that its potency can be affected by the water pH and organic matter; the chlorine becomes less effective at sanitizing water as the pH increases. The peak range of chlorine effectiveness is between 6.0 to 7.5 pH because in that range chlorine forms hypochlorous acid, which is "…20 to 30 times as effective as hypochlorite" (Parke & Fischer, 2012). It is suggested by Fischer (2013) that 2 ppm (parts per million) at 6.0 pH controls pathogens *Pythium* and *Phytophthora*.

Chlorine gas is a regulated substance that is very effective at disinfecting water. The use of chlorine is highly regulated in the United States, and is under the jurisdiction of Homeland Security (Source Watch, 2011). Large chemical companies are located in populated dense areas and may be susceptible to terrorist threats, thus various laws have been proposed in Congress regulating chlorine gas (109th Congress, 2008; 114th

Congress, 2015). Compliance with stricter laws may add to the cost and hassle of chlorine in the future.

Ozone treatment is used similarly to chlorine. As Fischer (2013) describes "[o]zone controls algae and pathogens in irrigation water by oxidizing constituents of the cell walls before it penetrates inside the cell wall and oxidizes the enzymes, proteins, DNA, RNA, and cell membranes" (Fischer, 2013). Ozone treatment can be an effective tool to help prevent disease outbreaks in nurseries that recapture water; however, that water must be clean for ozone treatment to be effective. According to the EPA (Environmental Protection Agency),"[m]ost wastewater treatment plants generate ozone by imposing a high voltage alternating current (6 to 20 kilovolts) across a dielectric discharge gap that contains an oxygen bearing gas" (EPA, 1999b). The advantages of ozone are short contact time, on-site generation, and no harmful residuals due to its rapid decomposition, while the disadvantages are that low dosages may be ineffective, ozone can be corrosive, and the cost of implementation and upkeep may be relatively high compared to other disinfecting materials (EPA, 1999b). Ozone use is more prevalent in European nursery use than in the United States.

Copper ionization is another technique to treat organic matter and pathogens in ponds and "…has been used for centuries as a fungicide, mostly in the form of copper sulfate or mixed with lime as Bordeaux mixture" (Fischer, 2013). Copper ions exploited by electric currents, which are produced during copper ionization, are toxic to pathogens and can be used to treat water (Parke & Fischer, 2012).

Ultraviolet (UV) light treatment is used to combat pathogens in water. Of the respondents to the Cultice survey (2013), three of the forty-four recycling nurseries indicated that they use UV light. The effectiveness depends on such factors as the wavelength at which the UV light is used. The UV light acts to disrupt the genetic makeup of the pathogen cells (Parke & Fischer, 2012). UV light can be an effective tool for disinfecting and sterilizing water.

Hong (2014) outlines other low cost methods that could also be used to possibly reduce or eliminate pathogens in water supplies. He urges re-routing runoff flow paths and also expanding the size and depth of sedimentation ponds. The main purpose of these techniques is to increase the time that pathogens die before being reintroduced to plants.

These BMPs provide a cursory overview of pathogen mitigation practices used in nurseries. If a nursery is engaged in recapturing and recycling water, it can be assumed that they are also very conscious of their water usage. There are a variety of techniques that can be implemented to irrigate efficiently.

Of the BMPs and techniques listed, chlorine is the most popular and is widely used. Chlorine is used because it is cost-effective and potent in dealing with pathogens. However, there are disadvantages to using chlorine. Chlorine residuals may be lethal to aquatic life and chlorine is risky to human health to store or ship. Also, some pathogens appear to have developed resistance (EPA, 1999a). Ozone, copper ionization, and UV systems have similar installation costs, but chlorine gas systems and chlorine tablets are less expensive[2]. The operating costs for all listed water treatment options are consistent with each other, less than $0.25 per 1,000 gallons (Fischer, 2013). Capital costs vary widely, for example, the EPA, in 1998, estimated that a moderately sized ozone disinfection system would cost approximately $300,000, which can be amortized over

[2] The costs associated with chlorine, ozone, copper ionization, and UV include installation and operating costs.

time (EPA, 1999b). Implementation of all these BMPs may require large upfront costs for the nurseries.

Capital budgeting is one way to assess costs of projects of varying life spans, and will be used to analyze costs within this study. "The analysis of capital investment has attracted particular attention because of the lasting effect of this type of cash outlay upon the fortunes of a firm. Investment in land, plant, and equipment typically produces services for a long period of time (p.3)" (Johnson, 1977). There are a variety of factors that affect capital budgeting related to outlays, such as interest rates, project time frame, discount rates, and salvage values (Wilkes, 1977). Capital budgeting to be done in a rational way that shows the overall perceived costs and benefits of a proposed capital change over the life of the investment.

Within an annualized budget, projects can be compared using partial budgeting techniques. Partial budgeting is used to compare alternative costs and benefits from choice of a particular practice over another. Kay and Edwards (1994) synthesize the basics of the method:

> "A partial budget provides a formal and consistent method for calculating the expected change in profit from a proposed change in the farm business. It compares the profitability of one alternative, typically what is now being done, with a proposed change or new alternative" (p. 160).

The partial budget is a tool used to discern how different choices may affect the net revenue of a farm, or in this case, a nursery.

A partial budget includes four distinct parts: 1.) additional costs, 2.) reduced revenue, 3.) additional revenue, and 4.) reduced costs. The outputs from the procedure or technology currently in use, which could be called the “defender,” relate to additional costs and reduced revenues. Similarly, the hypothetical option, or “challenger,” is related to the reduced costs and additional revenues (Rutgers Cooperative Extension, 2014). The *ceteris paribus* assumption is that only those elements of choice are examined in the partial budget. In other words, *ceteris paribus* assumes that all other factors, such as use of gas for trucks or overhead for support staff, will stay constant. There must be an assumption in the use of partial budgeting that all other factors in the farm or nursery shall remain the same within the context of the hypothetical budgeting. Olsen outlines the importance of keeping variables unaffected by the choice constant as, “[o]nly those items that are subject to change are considered in the partial budget analysis (p. 99)” (Olson, 2003). The partial budget is a powerful tool when assumptions are clearly delineated in the methodology and applied to the case being analyzed.

Enterprise budgets for horticultural nurseries provide useful information for partial budgets. In the 1980s, the Southern Cooperation Series published a sequence of bulletins on the costs of establishing and operating field nurseries, which are germane to the study as a way to understand nursery budget strategies. The bulletins focused on a wide variety of nurseries and plant types. The focus was on climactic zones 7, 8 and 9, which include most of the southeastern region of the United States. One bulletin concerned the costs of balled and burlapped trees of Tennessee Dogwood growers and others reported on the overall cost of starting and sustaining a nursery. A main goal of these publications was to assess variation between small and large nurseries (SAAESD, 1943-2015).

There was considerable detail in the description of nursery parameters in the bulletins. Variable costs included containers, mixing soil, polyethylene film, liners, chemicals, machinery and equipment, and hourly labor. Fixed costs were general overhead and costs associated with capital outlays, such as depreciation, interest, repair, insurance, and taxes. For this study, taxes, insurance, and repairs will not be analyzed as it would be difficult to assess for each individual nursery, and are assumed not to be affected by the water source. The SAAESD bulletins examined a monotype nursery so that results could be compared across nurseries of different sizes.

The cost accounting measures in these studies estimated capital outlays required for each type of nursery. Variable and fixed costs were estimated as they pertained to container production, such as fixed cost estimated over the life of the item and variable cost on a per year basis. In 1987 (using 1986 prices), the investment cost of starting a small (16 acre) container nursery was $392,643. A larger nursery of 32 acres would require $668,536 (also in 1986 prices). These estimates include land improvements, machinery and equipment, and buildings (SAAESD, 1986).

These bulletins focused on the total costs relating to running a nursery. The partial budgets for this study elaborate on this research, taking the costs of an existing water source and comparing them to an alternative option that could be chosen. The partial budgets will use the same type of technique, but only focus on a limited number of factors compared to the SAAESD bulletins. The partial budget techniques will not analyze the overall operations costs of the nursery, but rather focus on current practices and feasible alternatives for recapturing and recycling water. Theses bulletins will act as a guide in assessing the way in which variable and fixed costs of nurseries can be extrapolated. These costs will then be used in the partial budgets similar to the following studies.

Brennan et al. (2008) analyzed the investments required by irrigation with recycled water using partial budgeting on a mixed-crop farm in Queensland, Australia. The budgeting assessed economic effects of recycling water on a farm. A variety of fixed costs and variable costs were examined as well as the capital infrastructure. The model assessed breakeven prices and the profitability resulting from alternate circumstances (Brennan et al., 2008).

A similar study on horticulture and large scale crop farms was conducted in New South Wales, Australia in 2008 by Khan et al. The study focused on the hydrologic and economic consequences of water saving in an irrigated system in a non-nursery operation using a partial budgeting approach. The three measures examined in the partial budgeting analysis were: net benefits per megalitre (million liters) of water saved per year, annualized cost per megalitre saved, and the investment's breakeven year. The results indicated significant gains could be realized by implementation of water recycling technologies (Khan, Abbas, Gabriel, Rana, & Robinson, 2008).

Bekunda and Manzi (2003) used a partial budget to assess nutrient depletion on seven small farms in the highlands of Uganda, (Bekunda & Manzi, 2003). Ørum et al. (2010) assessed the incentives that farmers can receive to save water through implementing new irrigation techniques in Serbian tuber production (Ørum, Boesen, Jovanovic, & Pedersen, 2010). In 2013, Halloran et al. compared different productivity constraints in Maine potato production using partial budgeting (Halloran, Larkin, DeFauw, Olanya, & He, 2013). The difference in this study is the use of recycling techniques on horticultural operations as the subject of analysis. The partial budget has proven that it can be flexible and applicable in many different scenarios. The use of the partial budget in this project will be outlined in the following section.

Chapter 3 Methodology

This thesis analyzes factors that contribute to the decision of an ornamental horticulture nursery to whether or not to switch from surface, pond, or municipal sources irrigation water, well water, to recapturing and recycling water. Partial budget analysis is used to quantify irrigation costs with alternative or conventional water sources. Sensitivity analysis is used to evaluate how robust the results are to changes in cost parameters. The costs and returns of the partial budgets were estimated from information gathered through direct visits to nurseries or by estimation of factors and prices using secondary sources

From the visits and questions asked, it seems that every nursery is engaged in similar practices to capture and recycle water but those practices differ depending on the location and the endowment of resources for the operation and all or a proportion of total irrigation water was supplied by recapture and recycle. Irrigation water used on a normal summer day was requested, and off-season water use was estimated as a proportion of summer use. The problems and goals of each nursery are very similar but the way in which they cope with the requirement of a reliable and safe source of water depends on their location. Each nursery finds a different way to address problems of acquiring water and degrees of perceived pathogen risk based on their resources. The case studies and subsequent discussions outline these concerns and costs.

Nurseries were visited to gather data on the ways in which they handle recapturing and recycling of irrigation water. Selected nurseries in Pennsylvania, Maryland, and Virginia were visited during the summer of 2014 through the winter of 2015. The visits were used to assess the physical characteristics of the nursery and to learn about what steps have or have not been taken to recycle water. The visits were also an opportunity to learn what factors led the nursery to choose recycling originally. The nurseries not only differed in physical characteristics but also in the size and scope of products offered for sale, as well as the method of sale (wholesale, retail, re-wholesale, or combinations thereof). Some nurseries were small family operations that focused on on-farm or local retail store sales. Others were large scale businesses with dozens of workers specializing in wholesale or re-wholesale marketing. The market of each nursery is different some service multiple cities whereas others service small rural communities. Each of the nurseries was unique, but patterns became apparent pertaining to the factors that influenced their production decision to begin recycling.

All nurseries visited used capture and recycling as their main water source. Therefore, synthetic case studies were completed for nurseries having well water as their main water source and who might consider recycling as an option. These case studies were based on aggregate characteristics from nurseries within the Cultice (2013) survey. Synthetic large and small nurseries were considered. These characteristics from the survey responses form the basis for the landscape formulas and other assumptions that are used to construct the partial budgets.

Partial budget analysis is an important tool to evaluate a defender, or current technology, versus a challenger, or viable alternative. Rutgers Cooperative Extension (2014) outlined the four components to a Partial Budget in *Partial Budgeting: A Financial Management Tool*. A partial budget only considers those characteristics or factors that differ between the defender and challenger options; nothing else is included in the budget as per the *ceteris paribus* assumption. The defender portion for this study is divided into two sections; one including additional costs and the other being reduced returns. The challenger has sections of reduced costs and additional returns.

Additional costs are costs associated with the current practice (defender). For example, if the defender is uses recapture and recycle, a cost might be excavating a storage pond. Reduced returns are the profits, or returns, forgone when using the defender. In the case of recapture and recycle, a reduced return might be loss of income from land taken out of production and used for the capture pond. The additional returns are new profits that would be gained if the defender is selected. For example, if the challenger is municipal water, a holding pond might be needed to store municipal water to meet peak pumping demands. Additional returns in that case are the returns from producing plants on land that would otherwise be devoted to the holding pond. The reduced costs are distinguished by the outlays that would not be sustained if the defender were selected (Rutgers Cooperative Extension, 2014). For example, if the challenger is municipal water, a reduced cost might be the cost of purchasing municipal water. These four estimates are the foundation of the partial budget and encompass the way that alternative water sources are evaluated from a nursery operation perspective.

The technologies used for recapturing and recycling or for alternatives can be expensive and initial investments and capital costs may be high relative to the annual returns. The costs for the nursery budgets include initial capital costs, variable costs, and fixed costs. Fixed costs are capital items whose entire price is amortized over a set time period related to a set interest rate; while the variable costs are other annual costs than can fluctuate from year to year. The capital cost is the full investment required for achievement of a venture (Park & Allaby, 2013). Annual variable costs change depending on the number of units used or produced, while fixed costs are characterized as expenditures which must be paid regardless of the level of production (Black, 2012).

Due to the large cost differences among the nurseries, assumptions were made to allow for comparison between diverse operations. All costs were before-tax measures and the same interest rates were used for calculations involving capital outlays and the amortization schedule[3]. Taxes were not incorporated because this analysis is involved with one portion of the operation not the entire business.

Capital costs were amortized. Amortization is an accounting technique that distributes the cost of an item over its useful life in order to annualize costs and returns. The amortization formula used for each item was composed of three variables: the principal, the interest rate, and the time period. The principal is the total cost of the good or task and is characterized as P. The interest is the rate that is paid for the principal over the time period and is represented by I. Lastly, the time frame is represented by n, and is the total time in which the investment needs to be repaid. It is assumed that the repayment period and the useful life of the investment are equal. Amortization requires a discount or interest rate which represents the firm's weighted average cost of capital, a combination of interest on borrowed funds and opportunity cost of equity capital used in the investment over a given time frame (Boehlje & Eidman, 1984). The annual repayment is constant over the entire investment life. The payments are assumed to be annualized so they can be analyzed on a yearly basis; consequently making cash flows in the short run manageable and consistent. The investment life was different for various items as they relate to the size of the principal and the useful life of the item. The annualized cost is estimated with the following formula (myAmortizationChart, 2015):

[3] All calculations can be found in Appendix A.

Equation 1

$$\boldsymbol{Annual\ Payment} = \frac{\boldsymbol{I * P * (1 + I)^n}}{\boldsymbol{(1 + I)^n - 1}}$$

Costs are amortized at a 6.38% nominal rate based on current loan rates for long term loans of the Farm Credit System of Virginia (Farm Credit Systems of Virginia, 2014). However, the real interest rate must account for the inflation rate, which, in fall 2014, is 1.70% (Trading Economics, 2014). Therefore the real inflation rate used is 6.38% – 1.70% = 4.68%[4]. Real rates for other time horizons were calculated similarly as shown below (Table 3-1). Amortization tables are based on the real rate of interest. The output assumes that there is no salvage value from the items amortized.

The useful life of the item is an important part of the amortization process. The time frame and amortization cover the usable life of an item. Some of the time frames in this study are as short as 4 to 5 years, such as high intensity filters. For larger, longer term commitments, an upper end period of time being 30 years was given by the Farm Credit System of Virginia. The 30 year useful life is generally applied to regrading, remodeling, and other items that have a long life span. Interest rates of other time periods were also found from the Farm Credit System of Virginia. The loan rates used act as a proxy for the cost of capital dedicated to that time horizon and can be seen in Table 3-1 below:

[4] This is an approximation. The exact real rate is given by the formula (1+i)*(1+r) = 1+n where i, r, and n are the real rate, inflation rate, and nominal rate, respectively. Solving this equation gives the exact real rate of 4.6% (Boehlje & Eidman, 1984)

Table 3-1: Interest Rates by Length of Loan Life

Rates for Loans used in Amortization		
Inflation = 1.70%		
Years	Nominal Rate	Real Rate
30	6.38%	4.68%
15	5.60%	3.90%
10	4.95%	3.25%
4-5	4.25%	2.55%

The real interest rates were used in the amortization tables to spread the cost of an item over the useful life of the investment.

An example would be a nursery X that uses a widget with a life span of 5 years. The initial cost of a widget is $4,000 and using the real interest rate, from Table 3-1 , generates an example amortization table inTable 3-2: Example Amortization table.

Table 3-2: Example Amortization table[5]

Example Amortization Schedule for Widget							
Loan Amount	$4,000						
Interest Rate	2.55%						
Years	5						
Payments	$862						
Period	Beginning Balance	Payment	Principal	Interest	Cum. Principal	Cum. Interest	Ending Balance
1	$4,000	**$862**	$760	$102	$0	$102	$3,240
2	$3,240	**$862**	$780	$83	$780	$185	$2,460
3	$2,460	**$862**	$799	$63	$1,579	$247	$1,661
4	$1,661	**$862**	$820	$42	$2,399	$290	$841
5	$841	**$862**	$841	$21	$3,240	$311	$0

This Table 3-2 illustrates the amortization technique that is used in this project. The same process was used for all amortized values. The bolded amortization payments are constant throughout the life of the investment and allow for a consistent schedule of expenses.

[5] Cum. stands for cumulative

There are distinct differences for the budgets depending on whether recycling and recapturing is the defender or challenger. Example additional costs when recycling and recapture is the defender include regrading of the land, chlorine treatment systems, chlorine gas, extra stone for sediment removal, reused gas tanks, excavation of land, dredging of ponds, copper, bubblers, low fountain, truck loads of dirt, labor and capital moving soil, digging of ponds, filter, irrigation, bromine tablets, smart valve, algaecide, coloring and dye. The reduced returns include the opportunity cost of increasing the size of the catchment pond. An alternative or challenger is a feasible option which entails the reduced costs and additional returns. Reduced costs are those costs which would not be incurred if the defender is selected. If the defender is recycling and the challenger is municipal water, reduced costs include the city water connection, rate for the municipal water, treatment of municipal water in special situations, water availability charge, meter service charge, water meter, installation of water pipes, engineering, fees, and permits. If the challenger is well water, reduced costs include digging of wells, state permits for wells, installation of well pumps, electricity for wells pumps, installation of submersibles, wire, digging of the buffer pond, and installation of outlets. Additional returns include selling off excavated soil and the forgone opportunity costs associated with that buffer pond. These are all possible costs associated with the defender option being a recapture and recycle nursery.

The other alternative is that the defender is not recapturing and recycling, in which case, synthetic budgets were created[6]. In that case, the additional costs and reduced returns associated with recycling are labeled as the reduced costs and additional

[6] Exact explanations for both types of Partial Budgets and the calculations done for each item can be found in Appendix A.

returns as they would not be incurred if the defender (municipal water or well water) is selected.

Two items that are closely related are the recapture pond and the buffer pond. The pond cost is related to the physical dimensions of the ponds of the case nurseries, which provided recycled irrigation water to the operation. The buffer pond for the well water or municipal water source holds water in case of an emergency when plant needs exceed the pumping capacity of the source. Growers typically have a reserve capacity on site for emergency situations; within this study it is assumed that seven days of normal water use is stored on site in all scenarios. This emergency system would be supplied by the current system of water extraction.

The opportunity costs of the pond are directly related to the forgone profit in growing area that is occupied by the pond area. Therefore, the larger the pond the larger the forgone profit for the nursery. The cost of land is calculated as the possible profit that could be gained from a specific area of growing horticultural plants.

The synthetic budgets have the defender, as an existing well water option and the challenger as nursery modifications made for recapturing and recycling of water. Additional costs include digging of wells, pumps and installation, electricity for wells, and permits for wells. The reduced returns are the opportunity cost of the land used by the buffer pond. Likewise, the additional returns include the opportunity cost of the recapture pond. The reduced costs for the synthetic budgets are the chlorine system, smart valve, chlorine gas, regrading, digging of the recapture pond, and dredging of the pond.

The defender to challenger ratio is characterized by the defender being divided by the challenger to elicit a value. If this value is less than one, the defender is more profitable than the challenger. The smaller the value the more the defender is profitable. Conversely, if the value of the ratio is greater than one the challenger option is more profitable; and the larger the number the more profitable the option. If the value is equal to one then the options are equally as profitable.

Sensitivity analysis is used to estimate how varying opportunity cost of land can influence the net result of the partial budget. The effects of land cost variations are measured using sensitivity analysis as well to estimate the effects of forgone profits from land dedicated to recycling or buffer ponds. Using land for water retention and storage takes away space which might be more profitable as a growing area. The sensitivity analysis considers the opportunity cost tradeoff between the possibilities of increased sales versus water security This sensitivity analysis was used in the original partial budgets to see how changes in this factor would change the choice of least cost water source of each nursery.

The methods listed above seek to quantify the cost-efficiency of recapturing and recycling. Use of the partial budgets and sensitivity analysis offers the most desirable route to achieve the research objectives as outlined for nurseries in the mid-Atlantic region.

Chapter 4 Results:

A brief explanation and description of the nursery is given before each partial budget to provide a frame of reference. The analysis presumes that the initial layout of the nursery is flexible with recapture and recycling or an alternative source of water (municipal or well water) being options for future implementation. It assumes a blank canvas of land, at the inception of the nursery, and examines the least cost way to meet the nursery's irrigation needs. Many of the nurseries visited used containers as the principal plant production method. Table 4-1 shows the estimated growing area based on site visits.

Table 4-1: Container Nurseries

Nursery	Growing Area from Visits (Acres)	Percent Container From On-Site Visit Observations
A	2.5	60%
B	100	100%
C	200	100%
D	16.5	75%
E	105	2%
F	55	100%
G	22	23%
H	27	11%

The entire case study with explanations of measurements and calculations can be found in Appendix A.

Nursery A:

Nursery A is located in the Piedmont region of Virginia. To increase recycling of water on the premises, the owner recontoured the entire 2.5 acre horticultural operation in the 1980s. For this operation, it is assumed that city water is available as an irrigation alternative. The city is also assumed to provide adequate irrigation water without interruptions. The water costs include a hook-up fee as well as a per gallon price of water for augmenting the available supply from precipitation but without recycling. The partial budget is separated into two distinct options: the defender, relating to recapturing and recycling, and the challenger, relating to piping municipal water. The defender costs include regrading the field, an imbedded stone strainer, three water tanks, and excavation for water tanks. Costs for the challenger option are comprised of a water availability fee, a yearly rate for city water, a water connection charge, a meter service charge, and a buffer tank for water. The capital investment costs associated with Nursery A include regrading land, stone filter, reused gas tanks, excavation for gas tanks, water availability fee, water connection, and a single reused buffer gas tank area. These costs were amortized using Equation **1** from the methodology chapter. The only variable reduced costs are the rate for city water and the meter service charge. The

Table 4-2 indicates that, for Nursery A, it would be more profitable to recapture and recycle water than choose the municipal water option. Use of reused gas tanks, is a large cost item for the nursery when recapturing water; but that cost is offset by the cost for city water.

Table 4-2: Partial Budget Table: Nursery A[7]

Partial Budget Table: Nursery A			
Defender		Challenger	
Recapture/Recycling of Water		Municipal City Water	
Additional Costs		*Additional Returns*	
Regrading Land	$1,593	N/A	$0
Extra Stone(filters) (4in)	$125		
3 Reused Gas Tanks	$2,682		
Excavation of for 2 of the gas tanks	$92		
Reduced Returns		*Reduced Costs*	
N/A	$0	Water Availability Fee	$133
		Price for city water	$4,084
		Water Connection	$470
		Meter Service Charge	$900
		1 Reused Buffer Gas Tank	$518
Total	$4,493	Total	$6,105
Net Total (Defender -Challenger)	$ (1,612)		
Defender/Challenger Ratio	0.74		

Nursery B:

Nursery B, located in the coastal plains of Virginia, was founded in 1969 as a wholesale supplier and recently moved into retail sales. The nursery's transition into retail was precipitated by the financial crisis in 2008, and it has expanded to include three locations in the surrounding area. The nursery has a large recapture pond that is

[7] All explanations for every item can be found in the Case Studies within Appendix A

supplemented by the surrounding sediment ponds. The large pond is the irrigation withdrawal point, as the pump house and chlorine system are installed in this area. Water from the regraded land will flow down into a catchment pond area. Nursery B contains 100 acres and the owners surmise that 96 acres are regraded to recapturing water. The partial budget is separated into two distinct options: the defender, which relates to recapturing and recycling, and the challenger, which relates to piping in municipal water. The defender costs include regrading the field, dredging, a chlorine injection system, chlorine gas, copper algaecide, and the opportunity cost of the pond. Costs for the challenger option include selling off recontoured soil, opportunity cost of the buffer pond, cost to dig the buffer pond, a yearly price for city water, a water connection fee, and a meter service charge. The fixed costs associated with Nursery B included regrading land, dredging of recapture pond, chlorine system, digging of recapture pond, selling of regraded soil, city water hook up, treatment of public water, water availability charge, digging of buffer pond, and meter services charge were all fixed costs that were amortized using Equation 1.The variable costs are the chlorine, copper, opportunity cost of recapture pond, opportunity cost of buffer pond, and the rate of city water.

Table 4-3 specifies that Nursery B is far better off with the recapture and recycling of irrigation water than with the municipal option. The cost of municipal water is significant and is almost five times as much as the entire defender budget.

Table 4-3: Partial Budget: Nursery B [8]

[8] All explanations for every item can be found in the Case Studies within Appendix A

Partial Budget Table: Nursery B			
Defender		Challenger	
Recapture/Recycling of Water		Municipal City Water	
Additional Costs		*Additional Returns*	
Regrading Fields	$157,312	Selling off Regraded soil	$94,387
Dredging	$20,882	Opportunity Cost of Buffer	$15,382
Chlorine	$28,000		
Chlorine System	$179		
Copper	$661		
Digging Recapture Pond	$59,692		
Reduced Returns		*Reduced Costs*	
Opportunity Cost of Pond	$24,597	City water Hook up	$155
		Price for city water	$1,311,497
		Treatment for Public Water	$2,233
		Water Availability Charge	$38,841
		Meter Service Charge	$731
		Digging Buffer Pond	$37,322
Total	$291,322	Total	$1,500,548
	Net Total (Defender -Challenger)		
	$ (1,209,226)		
	Defender/Challenger Ratio		
	0.19		

Nursery C:

Nursery C is an operation established with the express intention to implement a recapture/recycle model of irrigation. The business started in 1999 and has 400 acres (200 of which are in production) in the coastal plain of Virginia. The partial budget is separated into the defender using recapturing and recycling and the challenger using municipal water. The defender costs include regrading the field, dredging, chlorine injection system, chlorine gas, a low fountain, a bubbler, and the opportunity cost of the land dedicated to the pond. The challenger option consists of selling off recontoured soil, the opportunity cost of the buffer pond, the cost to dig the buffer pond, a yearly rate for city water, a water connection fee, the installation of water pipes, and the engineering, fees, and permits related to the installation of water pipes. The largest costs with regard to both budgets are land costs, such as regrading, digging of ponds, and selling off soil. City water and engineering, fees, and permits were large costs and stand for a large part of the challenger budget. Recapturing and recycling water is far more cost-effective for nursery C. The chlorine gas, opportunity cost of the land used for the pond, reserve or buffer capacity, and the rate for city water are variable costs, while all other outlays are amortized using Equation 1. The cost of municipal water for nursery C approaches the total of the entire defender budget.

Table 4-4: Partial Budget Table: Nursery C [9]

Partial Budget Table: Nursery C				
Defender			Challenger	
Recapture/Recycling of Water			Municipal City Water	
Additional Costs			*Additional Returns*	
Regrading Fields	$315,833		Selling off Regraded soil	$252,667
Dredging	$179		Opportunity Cost of Buffer Pond	$8,790
Chlorine systems	$1,822			
Chlorine Gas	$16,800			
Low Fountain	$234			
Bubbler	$854			
Digging Recapture Pond	$279,165			
Reduced Returns			*Reduced Costs*	
Opportunity Cost of Pond	$115,058		Price for city water	$652,550
			Water Meter 10" Install	$7,143
			Connection Fee	$2,381
			Installation of Water pipes	$61,400
			Engineering, Fees, Permits	$248,140
			Digging of Buffer Pond	$11,059
Total	$729,945		Total	$1,244,130
	Net Total (Defender -Challenger)			
		$ (514,185)		
	Defender/Challenger Ratio			
		0.59		

Nursery D:

Nursery D located in Maryland's Piedmont region has been in operation since 1980 and is comprised of 22 total acres with 16.5 acres in actual production. The defender is recapturing and recycling of water, and the challenger is drilling additional wells in the area. The defender costs comprise of the free soil to fill the upper lot, labor

[9] All explanations for every item can be found in the Case Studies within Appendix A

related to earth moving, chlorine, digging out ponds, filtering, additional irrigation pipes and drains, dredging, opportunity cost of land devoted to the pond, and increasing the size of the pond. The challenger costs are comprised of the buffer capacity, digging of three additional wells, permits for the wells, purchase and installation of well pumps, and electricity for well pump motors. The opportunity cost of the reserve pond in the challenger budget exceeds the entire defender budget. Nursery D has a small capture pond that does not include occupying area that could be used for other profit avenues, and an estimated buffer pond that is larger than the actual capture pond that is larger than the actual capture pond, as the current pond does not have sufficient capacity for seven days. The fixed costs of Nursery D include labor and capital to move soil, digging recapture ponds, filter, irrigation pipes and drains, dredging, an assumed hypothetical cost of increasing pond size, digging extra wells, permits for the wells, purchase and installation of well pumps, and digging of buffer pond; all fixed costs that were amortized using Equation **1** from the methodology chapter. The variable costs include chlorine purchases, opportunity cost of recapture and buffer pond, and the electricity for pumps. The nursery has a very small pond capacity that would need to be extended to complete the goal of seven days reserve water capacity.

Table 4-5: Partial Budget Table: Nursery D [10]

[10] All explanations for every item can be found in the Case Studies within Appendix A

Partial Budget Table: Nursery D				
Defender			Challenger	
Recapture/Recycling of Water			Digging of Wells	
Additional Costs			*Additional Returns*	
Fill of 150 truck loads	$0		Reserve or Buffer Capacity	$4,922
Labor & capital to move around soil	$444			
Chlorine	$70			
Digging of the ponds	$1,466			
Filter	$155			
Irrigation w/ pipes and drains	$63			
Dredging	$64			
Reduced Returns			*Reduced Costs*	
Opportunity Cost of the pond	$600		Digging of 3 extra wells	$829
Cost of Increasing Pond Size	$1,516		State permits for the wells	$71
			Installation and Purchase of Well Pumps	$430
			Electricity for Pumps	$389
			Digging of Buffer Ponds	$3,564
Total	$4,377		Total	$10,205
	Net Total (Defender -Challenger)			
		$ (5,828)		
	Defender/Challenger Ratio			
		0.43		

Nursery E:

Nursery E is a large operation in the Maryland Piedmont region, and began business 35-40 years ago. It currently specializes in re-wholesaling. The land is well contained as water flows to a central recapture point, and suitable for a recapture irrigation system. The entire property is 105 acres. The defender is recapturing and recycling, and the challenger is piping in municipal water. Herbicides and coppers are included in this budget at $500 and $2,000 annual cost respectively. The cost of water at this nursery is not a large outlay. The largest outlay for the challenger was $248,140 for engineering, fees and permits for digging a municipal pipe and was larger than the entire defender option. Nursery E has low relative costs associated with the recapture and recycle option while the challenger alternative would have to pipe water from a distance of five miles. The chlorine gas, herbicides, opportunity cost of the recycling and buffer ponds, yearly water fees, and rates for water are variable costs while all other outlays are amortized using Equation **1**.

Table 4-6: Partial Budget Table: Nursery E [11]

Partial Budget Table: Nursery E			
Defender		Challenger	
Recapture/Recycling of Water		Municipal City Water	
Additional Costs		*Additional Returns*	
Dredging	$1,187	Reserve or Buffer Capacity	$976
Bubblers	$747		
Herbicides	$500		
Copper	$2,000		
Chlorine System	$848		
Chlorine Gas	$2,240		
Digging of Recapture Pond	$113,057		
Reduced Returns		*Reduced Costs*	
Opportunity Cost of the Pond	$40,726	Price for city water	$23,236
		Water Meter 1" Install	$376
		Yearly Water Fees	$1,293
		Installation of Water Pipes	$8,848
		Engineering, Fees, Permits	$248,140
		Digging of Buffer Pond	$804
Totals	$161,306	Total	$283,673
	Net Total (Defender -Challenger)		
	$ (122,367)		
	Defender/Challenger Ratio		
	0.57		

Nursery F:

Nursery F is located in the coastal plains of Maryland. The entire complex is 50 to 60 acres, with 6 acres devoted to a state-of-the-art greenhouse system. A portion of the property is inhabited by a separate nursery business. Recycling of irrigation water was a main concern when a plan for designing and shaping the property was implemented. All of the land from greenhouses and outdoor nursery area funnels directly into a large pond with 2.5 million gallon capacity at the low point of the property. The pond is directly fed through runoff from irrigation or rain water. If the pond's water level gets too low, the

[11] All explanations for every item can be found in the Case Studies within Appendix A

pond can be supplemented from an onsite well. The well is equipped with a 10 horsepower motor that draws water from an aquifer less than 100 feet deep. If water recycling were not an option, the only other feasible alternative would be to drill more wells, as the closest municipal lines are miles away. Therefore, the only option for Nursery F from the outset was to either design a recycling operation or to drill more wells. Chlorine gas, bromine tablets, coppers, opportunity cost of the pond, reserve or buffer capacity, and electricity for pumps are variable costs while all other outlays are amortized using Equation **1**.

The defender is recapturing and recycling, and the challenger is drilling additional wells. The defender costs

Table 4-7: Partial Budget Table: Nursery **F** indicate a nursery which is better suited for obtaining water by digging wells rather than recapturing and recycling water. Well digging would cost $9,120, while the defender costs would be $177,870, primarily for regrading land to capture as much water as possible.

Table 4-7: Partial Budget Table: Nursery F [12]

Partial Budget Table: Nursery F			
Defender		Challenger	
Recapture/Recycling of Water		Digging of Wells	
Additional Costs		*Additional Returns*	
Copper	$587	Opportunity Cost of Buffer Pond	$4,816
Bubbler	$107		
Chlorine	$5,600		
Bromine tablets	$1,000		
Regrading	$91,330		
Dredging	$9,588		
Chlorine Systems	$179		
Smart Valve	$670		
Digging of Recapture Pond	$29,516		
Reduced Returns		*Reduced Costs*	
Opportunity Cost of Pond	$39,293	Drilling of additional wells	$829
		Installation of Pumps	$1,767
		Permits for Additional Wells and Water	$71
		Electrical for additional wells	$564
		Digging of Buffer Pond	$1,073
Total	$177,870	Total	$9,120
Net Total (Defender -Challenger)	$168,750		
Defender/Challenger Ratio	19.50		

Nursery G:

Nursery G is a business located in the Ridge and Valley region of Pennsylvania that was started in 1939 with 22 acres of land. The nursery has expanded through the purchase of neighboring properties. The defender is recapturing and recycling, and the challenger is well drilling in Table 4-8: Partial Budget Table: Nursery G . A challenger option requires that well water be piped from an off-site location, because the owner

[12] All explanations for every item can be found in the Case Studies within Appendix A

indicated that there are no aquifers in the immediate area. The total cost of piping is nearly $50,000 and is the largest portion of the budget. The algaecide, coloring, opportunity cost of the pond, reserve or buffer capacity, and electricity for pumps are variable costs while all other outlays are amortized using Equation 1.

Table 4-8: Partial Budget Table: Nursery G [13]

Partial Budget Table: Nursery G				
Defender			Challenger	
Recapture/Recycling of Water			Digging of Wells	
Additional Costs			*Additional Returns*	
Algaecide	$1,527		Reserve or Buffer Capacity	$984
Coloring	$1,457			
Dredging	$9,476			
Digging of Recapture Pond	$31,622			
Reduced Returns			*Reduced Costs*	
Opportunity cost of pond	$11,162		Digging of Additional wells	$613
			Installation of Submersibles	$1,351
			Piping from 1 mile away	$1,394
			Electricity for Pumps in wells	$145
			Permits for Piping	$49,628
			Wire for Wells	$241
			Installation of Outlets	$646
			Digging of Buffer Pond	$828
Total	$55,243		Total	$55,831
		Net Total (Defender -Challenger)		
		$ (588)		
		Defender/Challenger Ratio		
		0.99		

Nursery H:

Nursery H has been a family operated business since 1945 and is located on top of a mountain in the Ridge and Valley region of Pennsylvania on 27 acres. The nursery has eight to ten part time workers, with the owner being the only full time employee. There is no well water on site due to the elevation and location of the nursery. The water is

[13] All explanations for every item can be found in the Case Studies within Appendix A.

supplied by the local municipality, but this water source is not often used. The water from the municipality acts more as an insurance policy for the site, in case of drought.

The operation uses recycled irrigation water only for their container production. A majority of the land is a field nursery with a small proportion grown in containers. Rain water irrigates most of the land but there are two ponds located on the property, so they are able to capture runoff and recycle. The partial budget includes the defender, recapturing and recycling, and the challenger, municipal water uses. The defender costs, in Table 4-9, include dredging ponds and digging of recapture ponds. The challenger option is mainly composed of the cost of the buffer pond and cost of purchasing municipal water. The municipal water option was more cost-effective than recycling irrigation water due to high costs associated with digging the recapture pond. The fixed costs associated with Nursery H including digging of recapture ponds, dredging, and digging of buffer ponds were all amortized using Equation 1 described in the methodology chapter. The variable costs are the dye, opportunity cost of recapture, buffer pond, and cost of municipal water.

Table 4-9: Partial Budget Table: Nursery H[14]

[14] All explanations for every item can be found in the Case Studies within Appendix A.

Partial Budget Table: Nursery H			
Defender		Challenger	
Recapture/Recycling of Water		Municipal Water	
Additional Costs		*Additional Returns*	
Dye	$ 511	Oppotuinty Cost of Buffer Pond	$ 7,969
Dredging Ponds	$ 1,284		
Digging of Recapture Pond	$ 34,275		
Reduced Returns		*Reduced Costs*	
Opportunity Cost for Ponds	$ 10,648	Price for city water	$ 7,197
		Digging of Buffer Pond	$ 7,232
Total	$ 46,719	Total	$ 22,397
Net Total (Defender -Challenger)	$24,322		
Defender/Challenger Ratio	2.09		

Six of the eight case nurseries have a defender to challenger ratio below one indicating that the option of recapturing and recycling water is more profitable for their business than the next best alternative. Two nurseries with a ratio greater than one were located in Maryland (F) and Pennsylvania (H). The nursery in Maryland experienced large costs related to regrading and inconsequential costs associated with the drilling of wells. Nursery F was an operation with large water reserves for recycling supplemented by water from a low producing well on site. The nursery H analysis showed a municipal water source that would be less costly than recapture and recycling of irrigation water. The main obstacle for the business was digging a pond large enough to hold the necessary amount of water for recycling irrigation.

Synthetic Small and Large Nurseries:

Nurseries that do not recapture and recycle irrigation water are common in the horticulture industry in this region. To this point, there are no case studies describing a nursery transitioning from non-recycling irrigation to recapturing/recycling. Only forty-two of the 435 surveys sent out from the Cultice survey. Two synthetic nurseries, one large and one small, have been created based on survey results(Cultice 2013). Revenue responses were used to indicate whether responding nurseries would be considered small or large. Nurseries that did not answer the revenue question were omitted from further analysis. Any nursery with revenue greater than $500,000 was considered large (35 nurseries), and any nursery with a revenue less than or equal to $500,000 was considered to be small (160 nurseries). Because of the additional state regulatory challenges for nurseries, both nurseries were assumed to be in the Maryland Piedmont and to be using large, deep wells to extract water. The wells for both nurseries are assumed to have a depth of 500 feet and to produce 20 gallons per minute.

Small Synthetic Nursery:

The characteristics of the small nurseries are as follows: The majority of water supplied is from wells (with the remainder from rainfall), because 120 out of 160 operations indicated wells as the primary source of irrigation water from Cultice (2013). Of surveyed nurseries, 92% of irrigation water is supplied by wells. Of the 160 nurseries which indicated the amount of water used, 135 indicated that they use between 0 and 100,000 gallons per day. After weighting the responses to include the midpoints of the ranges of daily use and multiplying them by the number of nurseries in that category, water use for the synthetic nursery is estimated to average 55,036 gallons per day. The average number of acres of the 160 small nurseries is 13.6 acres. Of the 160 nurseries, very few used water pathogen mitigation techniques for irrigation water and no such practices are assumed for the defender budget. From the revenue perspective, it is assumed that the synthetic nursery would sell $104,297, based upon surveyed nurseries’ estimated operating costs and revenues. This provides an opportunity to assess operating profit per square foot and estimated opportunity cost of land devoted to recycling or buffer ponds. Regrading is a key aspect of conversion to recycling and it is assumed that the cost per acre would be similar to Nursery A's regrading cost at $19,796 per acre. For the 10.21 acres, cost would total $202,097 and be amortized at $12,664 annually. The 10.21 acres is 75% of the assumed 13.6 acres and was consistent with areas of production on the nurseries visited. In the partial budget, the defender is drilling for irrigation water, and the challenger is recapturing and recycling of irrigation water as shown in Table 4-10. Results indicate it is more profitable to use well water than recycle. The nursery would have extensive regrading costs based on 75% of the land being regraded.

Table 4-10: Partial Budget Table: Small Synthetic Nursery[15]

[15] All explanations for every item can be found in the Case Studies within Appendix A_.

Partial Budget Table: Small Synthetic Nursery				
Defender			Challenger	
Well Water			Recapture/Recycling of Water	
Additional Costs			*Additional Returns*	
Digging of wells	$8,290		Recapture pond	$5,368
Pumps and Install	$860			
Electricity for wells	$842			
Permits for wells	$120			
Digging of Buffer Pond	$818			
Reduced Returns			*Reduced Costs*	
Buffer pond	$993		Chlorine system	$179
			Smart Valve	$670
			Chlorine gas	$1,540
			Regrading	$6,506
			Digging of the Pond	$13,771
			Dredging	$5,178
Total	$11,923		Total	$33,212
	Net Total (Defender -Challenger)			
		$21,289		
	Defender/Challenger Ratio			
		0.36		

Large Synthetic Nursery:

Of the 36 large operations from Cultice (2013), 61% were exclusively wholesale nurseries. Thirty-one of the thirty-six large nurseries in the Cultice (2013) survey obtained some portion of irrigation water from well water. In order for the large nursery and small nursery to be consistent, it is assumed that the large nursery obtains all its irrigation water from wells. The average nursery production area for the 36 surveyed nurseries is 88.9 acres. Weighted average irrigation water use per day is estimated at 232,258 gallons per day, which is consistent with other nurseries visited of a similar size. The average usage per year is estimated at 52,258,050 gallons based on the assumed water uses in winter and summer seasons. Of the thirty-six nurseries responding to the survey, only eleven used some form of water pathogen mitigation techniques; therefore, no such techniques are assumed for the defender budget. Regrading is a key aspect of conversion to recycling and it is assumed that the cost per acre would be similar to Nursery B's regrading at $25,105 per acre. For the 66.7 acres regrading would cost $1,674,258 and be amortized at $104,912 annually. The 66.7 acres is 75% of the assumed 88.92 acres and was consistent with areas of production on the nurseries visited.

Table 4-11: Partial Budget **Table: Large Synthetic Nursery** contains costs for the defender, well water, and the challenger, recapturing and recycling of irrigation water. The analysis shows that if available, it is more profitable to use well water exclusively than recycling and recapturing. The nursery had extensive regrading costs based on 75% of the land being regraded.   Pond digging was more costly than the entire well water option.

Table 4-11: Partial Budget Table: Large Synthetic Nursery [16]

[16] All explanations for every item can be found in the Case Studies within Appendix A.

Partial Budget Table: Large Synthetic Nursery				
Defender			Challenger	
Well Water			Recapture/Recycling of Water	
Additional Costs			*Additional Returns*	
Digging of wells	$34,542		Recapture pond	$50,491
Pumps and Installation	$3,584			
Electricity for wells	$3,508			
Permits for wells	$429			
Digging of Buffer	$3,449			
Reduced Returns			*Reduced Costs*	
Buffer pond	$4,764		Chlorine system	$179
			Smart Valve	$670
			Chlorine gas	$6,497
			Regrading	$104,912
			Digging of the Pond	$123,328
			Dredging	$42,865
Total	$50,276		Total	$328,942
	Net Total (Defender -Challenger)			
		$278,666		
	Defender/Challenger Ratio			
		0.15		

Cost Matrix:

A cost matrix was constructed to summarize the costs for each nursery for the defender and challenger options. The items in

Table 4-12,

Table **4-13** and, Table 4-14 are listed on the left hand side while the cost and percent of total costs is listed in the columns corresponding to each nursery.

Table 4-12: Defender Cost Matrix

Cost Matrix for Visited Nurseries: Defender																	
Defender																	
	Nursery	%	Nursery	%	Nursery	%	Nursery	%	Nursery	%	Nursery	%	Nursery	%	Nursery	%	Average for Item
Item	***A***	***A***	***B***	***B***	***C***	***C***	***D***	***D***	***E***	***E***	***F***	***F***	***G***	***G***	***H***	***H***	
Type of Water Option	***Water Recycling***		***Water Recycling***		***Water Recycling***		***Water Recycling***		***Water Recycling***		***Water Recycling***		***Water Recycling***		***Water Recycling***		
Regrading	$ 1,593	35.46%	$ 157,312	54.00%	$ 315,833	43.27%					$ 91,330	51.35%					46.02%
Extra Stone	$ 125	2.79%															2.79%
Excavation 2 Gas Tanks	$ 92	2.06%															2.06%
Chlorine System			$ 179	0.06%	$ 1,822	0.25%			$ 848	0.53%	$ 179	0.10%					0.23%
Smart Valve											$ 670	0.38%					0.38%
Cost of Chlorine			$ 28,000	9.61%	$ 16,800	2.30%	$ 70	1.60%	$ 2,240	1.39%	$ 5,600	3.15%					3.61%
Dredging			$ 20,882	7.17%	$ 179	0.02%	$ 64	1.45%	$ 1,187	0.74%	$ 9,588	5.39%	$ 9,476	17.15%	$ 1,284	2.75%	4.95%
Coppers			$ 661	0.23%					$ 2,000	1.24%	$ 587	0.33%					0.60%
Gas Tank	$ 2,682	59.69%															59.69%
Opp Cost of Recapture Pond			$ 24,597	8.44%	$ 115,058	15.76%	$ 600	13.70%	$ 40,726	25.25%	$ 39,293	22.09%	$11,162	20.20%	$ 10,648	22.79%	18.32%
Low Fountain					$ 234	0.03%											0.03%
Bubbler					$ 854	0.12%			$ 747	0.46%	$ 107	0.06%					0.21%
Filter							$ 155	3.54%									3.54%
Fill in Area/Increase Pond Size							$ 1,516	34.64%									34.64%
Labor Moving Soil							$ 444	10.15%									10.15%
Digging of Pond			$ 59,692	20.49%	$ 279,165	38.24%	$ 1,466	33.49%	$ 113,057	70.09%	$ 29,516	16.59%	$31,622	57.24%	$ 34,275	73.37%	44.22%
Irrigation Pipes and Drains							$ 63	1.43%									1.43%
Herbicides									$ 500	0.31%							0.31%
Bromide Tablets											$ 1,000	0.56%					0.56%
Algaecide													$ 1,527	2.76%			2.76%
Coloring													$ 1,457	2.64%			2.64%
Dye															$ 511	1.09%	1.09%
TOTALS	$ 4,493	100.00%	$ 291,322	100.00%	$ 729,945	100.00%	$ 4,377	100.00%	$ 161,306	100.00%	$177,870	100.00%	$55,243	100.00%	$ 46,719	100.00%	

Table 4-13: Challenger Cost Matrix

Challenger	Cost Matrix for Visited Nurseries: Challenger																
	Nursery	%	Nursery	%	Nursery	%	Nursery	%	Nursery	%	Nursery	%	Nursery	%	Nursery	%	Average for Item
Item	***A***	***A***	***B***	***B***	***C***	***C***	***D***	***D***	***E***	***E***	***F***	***F***	***G***	***G***	***H***	***H***	
Type of Water Option	***Municipal Water***		***Municipal Water***		***Municipal Water***		***Well Water***		***Municipal Water***		***Well Water***		***Well Water***		***Municipal Water***		
Water Availability Fee	$ 133	2.19%	$ 38,841	2.59%					$ 1,293	0.46%							1.74%
Rate for City Water	$ 4,084	66.89%	$1,311,497	87.40%	$ 652,550	52.45%			$ 23,236	8.19%					$ 10,444	40.73%	51.13%
Gas Tanks	$ 518	8.48%															8.48%
Meter Install					$ 7,143	0.57%			$ 376	0.13%							0.35%
Water Hook Up Fee	$ 470	7.70%	$ 155	0.01%	$ 2,381	0.19%											2.63%
Meter Service Charge	$ 900	14.74%	$ 731	0.05%													7.40%
Selling off Soil			$ 94,387	6.29%	$ 252,667	20.31%											13.30%
Opp Cost Buffer Pond			$ 15,382	1.03%	$ 8,790	0.71%	$ 4,922	48.23%	$ 976	0.34%	$ 4,816	52.81%	$ 984	1.76%	$ 7,969	31.07%	19.42%
Digging of Buffer Pond			$ 37,322	2.49%	$ 11,059	0.89%	$ 3,564	34.92%	$ 804	0.28%	$ 1,073	11.77%	$ 828	1.48%	$ 7,232	28.20%	11.43%
Treatment of City Water			$ 2,233	0.15%													0.15%
Installation of Water Pipes					$ 61,400	4.94%			$ 8,848	3.12%			$ 1,394	2.50%			3.52%
Engineering, Fee, Permits					$ 248,140	19.94%			$ 248,140	87.47%			$49,628	88.89%			65.44%
Digging of Extra Wells							$ 829	8.12%			$ 829	9.09%	$ 613	1.10%			6.10%
State Permits							$ 71	0.69%			$ 71	0.78%					0.74%
Cost and Install of Well Pumps							$ 430	4.21%			$ 1,767	19.38%	$ 1,351	2.42%			8.67%
Electricity for Pumps							$ 389	3.82%			$ 564	6.18%	$ 145	0.26%			3.42%
Wire For Wells													$ 241	0.43%			0.43%
Install of Outlets													$ 646	1.16%			1.16%
TOTALS	$ 6,105	100.00%	$1,500,548	100.00%	$1,244,130	100.00%	$10,205	100.00%	$ 283,673	100.00%	$ 9,120	100.00%	$55,831	100.00%	$ 25,644	100.00%	

Table 4-12 shows costs for the recapturing and recycling option for each case nursery. The percentage costs are relative to the overall amount of cost for each individual operation. The percentages allow comparison of costs between nurseries of differing sizes (some percentages only apply to one nursery).

The largest costs for the defender option are land regrading, the opportunity cost of land for the capture pond, and pond excavation. Of the four nurseries needing regrading (A, B, C, and E), the regrading share of total cost was between 43%-54% of the total defender budget, with an average of 50% among the four. Seven of the eight nurseries had pond excavation as one of the highest expenses of the defender option. Two nurseries (E and H) incur more than 70% of the total cost for digging recapture ponds. The other nurseries (B, C, D, F, and H) averaged 33% for digging the recapture pond. Chlorine systems and chlorine gas for pathogen mitigation averaged 0.02% and 3.8% of the total cost of the defender, respectively. There are other miscellaneous costs associated with each nursery; however, for most nurseries regrading the land, the opportunity cost of land devoted to the pond, pond extraction, chlorine, and chlorine delivery systems were the most important items.

The challenger option, characterized by

Table **4-13**: Challenger Cost Matrix has different characteristics. The largest outlays include the cost of city water, engineering, fees, and permits, and finally the opportunity cost of land devoted to the buffer pond. City water for five of the eight nurseries is an alternative option (A, B, C, E, and H). The nurseries' alternative budget cost for city water ranged from 8% to 87% of the challenger budget with the average among the five nurseries of 52%. The engineering, fees, and permit costs were estimated if a nursery had to pump in water from a faraway source along municipal routes. These were important outlays for planning and implementing an alternative option to recapturing and recycling. The engineering, fees, and permits were used in three nursery alternatives (D, F, and G) and averaged 65% of the overall budget between operations. Seven of the eight nurseries have the opportunity cost of buffer ponds ranging from 0.28% to 35% of their overall budget with the average being 23%.

Table 4-14: Synthetic Nurseries Cost Matrix

Cost Matrix for Synthetic Nurseries								
Defender								
	Nursery		%		Nursery		%	
Item	*Synthetic Small*				*Synthetic Large*			
Type of Water Option	***Well Water***				***Well Water***			
Buffer Pond	$	993	8.33%	$	4,764	9.47%		
Digging of Extra Wells	$	8,290	69.53%	$	34,542	68.71%		
State Permits	$	120	1.00%	$	429	0.85%		
Cost and Install of Well Pumps	$	860	7.21%	$	3,584	7.13%		
Digging Buffer Pond	$	818	6.86%	$	3,449	6.86%		
Electricity for Pumps	$	842	7.06%	$	3,508	6.98%		
TOTALS	$	11,923	100.00%	$	50,276	100.00%		
Challenger								
	Nursery		%		Nursery		%	
Item	*Synthetic Small*				*Synthetic Large*			
Type of Water Option	***Water Recycling***				***Water Recycling***			
Regrading	$	6,506	19.59%	$	104,912	31.89%		
Chlorine System	$	179	0.54%	$	179	0.05%		
Smart Valve	$	670	2.02%	$	670	0.20%		
Cost of Chlorine	$	1,540	4.64%	$	6,497	1.98%		
Dredging	$	5,178	15.59%	$	42,865	13.03%		
Digging of Pond	$	13,771	41.47%	$	123,328	37.49%		
Opp Cost of Pond	$	5,368	16.16%	$	50,491	15.35%		
TOTALS	$	33,212	100.00%	$	328,942	100.00%		

Table 4-14: Synthetic Nurseries Cost Matrix is composed of the two synthetic nurseries which form a defender option relating to well water drilling in Maryland. The defender incurs five main costs: digging the wells, installation of well pumps, digging buffer ponds, electricity for pumps, and opportunity cost of buffer ponds. Together these two items account for more than 75% of overall costs for the defender option.

On the two synthetic nurseries, the largest costs for the challenger are pond digging, followed by regrading, the opportunity costs of land dedicated to the pond, and pond dredging every 15 years. The relative cost of chlorine and the chlorination system is minimal. The regrading costs are a function of the amount of soil moved, which varies substantially between the small and large nurseries. The soil removed is directly related to area of the operation reported by similar size nurseries from the Cultice (2013) survey. Therefore, regrading costs from visited nurseries of similar size to the synthetic nurseries were used to inform the synthetic calculations. The cost matrix illustrates that nurseries such as these would be better off to use well water rather than convert to recycling given the basic assumptions used in the case study. However, the results do not reflect the effects of opportunity cost of land. Sensitivity analysis is used to analyze this question.

Chapter 5 Sensitivity Analysis

The sensitivity analysis is conducted on the parameters that are of high importance to a recapturing and recycling decision. The analysis is implemented in light of the fact that key variables used in partial budgeting are subject to change. The partial budget will be regenerated to assess the effects of changes in the costs of key variables on the relative water supply costs of the challenger and defender.

Sensitivity analysis is typically used in economic studies [Gourieroux, Laurent &Scaillet (2000); Lenhart et al. (2002); Brumfield, Rimal, & Reiners (2000); Frey & Patil (2002)]. Gourieroux, Laurent, &Scaillet (2000) value risk of companies through sensitivity analysis (Gourieroux, Laurent, & Scaillet, 2000). Lenhart et al. (2002) use sensitivity analysis for physically based hydrological models (Lenhart, Eckhardt, Fohrer, & Frede, 2002). Brumfield, Rimal, & Reiners (2000) use sensitivity analysis to look at organic crop markets for farms using integrated crop management (Brumfield, Rimal, & Reiners, 2000). Frey &Patil (2002) outline different methods of sensitivity analysis that can be used for various problems (Frey & Patil, 2002). The methods covered were a combination of regression, nominal ranges, ANOVA, and break even.

The sensitivity analysis in this study focuses on \operating profit per acre. From visits with growers, the constraints of arable land and access to reliable water quantity and quality are the factors that most affect the expansion and decision to recapture and recycle. Looking to the Cost Matrix from Chapter 4, some of the largest costs relate to land: regrading, opportunity costs of the capture pond, and the opportunity costs of the buffer pond. Water is a crucial resource that needs to be analyzed, particularly the cost of obtaining water from wells or municipal services. The partial budgets may be affected in the future by costs of extraction methods; consequently, sensitivity analysis can be used in the investigation. The nurseries visited indicate that without a reliable source of water, the business could not exist; therefore, the potential effects of increased costs of water extraction alternatives to the recapturing and recycling technique must be taken into account. The land opportunity costs per acre and water price of extraction were found using different methods.

The land opportunity cost with regard to the catchment ponds was estimated from the Cultice (2013) survey results. The opportunity cost of land can be characterized as lost profit from land taken out of plant production which is taken up by pond area. The constrained land area could also limit the variety of possible plants available for the operation's customers. The data used for estimating land opportunity costs was constrained to nurseries which provided all information on operation's revenue, the costs for the entire nursery, and the total area of nursery growing space. The revenue question was represented as a series of ranges and the nursery's revenue was assumed to be at the midpoint of the range indicated by the respondent. In this case, operating profit is estimated by subtracting total costs from the midpoint of the revenue range, represented by

Equation 2 .

Equation 2

$$Operating\ Profit = \left(\frac{[Upper\ Limit\ of\ Revenue\ Range + Lower\ Limit\ of\ Revenue\ Range]}{2}\right) - Costs\ of\ Operation$$

The total costs are characterized by the nursery's answer to the question regarding their entire costs for nursery production, because the revenue was also for the entire nursery.

The operating profit is then divided by the total area of the nursery to estimate the total operating profit per square foot, characterized by Equation **3** .

Equation 3

$$Operating\ Profit\ per\ Square\ Foot = \frac{Operating\ Profit\ per\ Square\ Foot}{Square\ foot\ of\ production\ area\ for\ entire\ nursery}$$

The operating profit is used to estimate the forgone opportunities for operating profit associated with the catchment pond.

Problems did arise as revenue and costs pertained to different nurseries. For instance, the calculations showed one nursery losing over one billion dollars per acre due to erroneous entries for operating area or costs. The billion dollar amounts are an entirely unrealistic conclusion for a nursery, and it can be determined that a reporting or entering error is present within the data. This example nursery is not the only one to report an unrealistic operating profit per acre. The top 10% and bottom 10% of estimated profits were omitted, thus providing more robust estimates of operation profit. The 20% were omitted to assure that large outliers did not affect the estimates. The remaining 80% (116) respondents were recast to form five separate groupings based on revenue. The new groupings are characterized in Table 5-1: Regrouping of Nurseries based on Revenue. The groupings are divided to show the revenue groupings of the 12 possible categories from the Cultice (2013) survey questions. The 5 groups were recast to achieve a similar number of respondents in each category.

Table 5-1: Regrouping of Nurseries based on Revenue

Regroupings of Revenue question from the Cultice Survey			
Group	Revenue Group(s)	Revenue	N
1	1	Less than $25,000	24
2	2	$25,001 to $100,000	22
3	3-4	$100,001 to $500,000	35
4	5-6	$500,001-$1,000,000	16
5	7-12	$1,000,001 and greater	19

The descriptive statistics in Table 5-2: Nursery Operating Profit and Area **by Revenue Category** , were used to find the mean of each data group. The descriptive statistics show a 15% variation from the mean. The number of observations is so small for each group that a population sample at a 95% confidence would be infeasible. Therefore, 15% on either side of the mean is used to assess the sensitivity analysis. The 15% gives sufficient variability to test robustness regarding lowest cost water source. The upper and lower categories are indicated by adding or subtracting 15% from the mean as shown by Equation **4**.

Equation 4

$$Upper\ or\ Lower\ bounds = Mean\ \pm (Mean * 0.15)$$

Thus, the change can be seen at the 15% metric and will influence the operating profit per square foot.

Table 5-2: Nursery Operating Profit and Area by Revenue Category

The Upper, Mean, and Lower bounds of the sensitivity analysis as it pertains to Profit and Square Foot for each Nursery Group					
Profit					
Group	1 (Less than $25,000)	2 (Revenue between $25,001 and $100,000)	3 (Revenue between $100,001 and $500,000)	4 (Revenue between $500,001 and $1,000,000)	5 (Revenue above $1,000,001)
N	24	22	35	16	19
Mean	$ 9,073	$ 35,735	$ 168,815	$ 299,952	$ 1,744,119
15% of the Mean	$ 1,361	$ 5,360	$ 25,322	$ 44,993	$ 261,618
Upper	$ 10,434	$ 41,095	$ 194,137	$ 344,945	$ 2,005,736
Lower	$ 7,712	$ 30,375	$ 143,493	$ 254,959	$ 1,482,501
Square Foot					
Group	1 (Less than $25,000)	2 (Revenue between $25,001 and $100,000)	3 (Revenue between $100,001 and $500,000)	4 (Revenue between $500,001 and $1,000,000)	5 (Revenue above $1,000,001)
N	24	22	35	16	19
Mean	40,040	483,932	1,458,562	655,603	13,262,771
15% of the Mean	6,006	72,590	218,784	98,340	1,989,416
Upper	46,046	556,521	1,677,346	753,944	15,252,187
Lower	34,034	411,342	1,239,778	557,263	11,273,355

The descriptive statistics are represented by the mean of each group from Table 5-1: Regrouping of Nurseries based on Revenue as it relates to the operating profit and square feet. The following table represents the way in which the operating profit per square foot is calculated. Each group has nine operation profits per square foot associated with the descriptive statistics formed from the mean, upper, and lower values for the profit and square foot metrics. To get the operating profit per square foot, the profit must be divided by the square footage. Therefore, for each nine cell matrix, all combinations of the possible operating profits per square foot given the mean, upper and lower ranges are represented. For example, in group 1, the estimated profit per square foot for the upper operating profit and lower area in square feet would correspond to the upper range of operating profit ($10,434), and the lower would correspond to the lower range of square feet (34,034); producing a profit per square foot of $0.31 ($10,434/

34,034). Other estimated profits per square foot are calculated similarly in Table 5-3: Profit per Square Foot for Differing Nursery **Areas and Operating Profits** .

Table 5-3: Profit per Square Foot for Differing Nursery Areas and Operating Profits

Profit Per Square Foot as Relating to the Sensitivity Analysis of the Characteristics of Each Group (Profit/Sq Ft)			
Group 1 (Revenue Less than $25,000)			
	Square Feet		
Operating Profit	Upper	Mean	Lower
Upper	$0.23	$0.26	$0.31
Mean	$0.20	$0.23	$0.27
Lower	$0.17	$0.19	$0.23
Group 2 (Revenue between $25,001 and $100,00)			
	Square Feet		
Operating Profit	Upper	Mean	Lower
Upper	$0.07	$0.08	$0.10
Mean	$0.06	$0.07	$0.09
Lower	$0.05	$0.06	$0.07
Group 3 (Revenue between $100,001 and $500,000)			
	Square Feet		
Operating Profit	Upper	Mean	Lower
Upper	$0.12	$0.13	$0.16
Mean	$0.10	$0.12	$0.14
Lower	$0.09	$0.10	$0.12
Group 4 (Revenue between $500,001 and $1,000,000)			
	Square Feet		
Operating Profit	Upper	Mean	Lower
Upper	$0.46	$0.53	$0.62
Mean	$0.40	$0.46	$0.54
Lower	$0.34	$0.39	$0.46
Group 5 (Revenue above $1,000,001)			
	Square Feet		
Operating Profit	Upper	Mean	Lower
Upper	$0.13	$0.15	$0.18
Mean	$0.11	$0.13	$0.15
Lower	$0.10	$0.11	$0.13

An example for Nursery E is shown in Table 5-4: Operating Profit per Square Feet Sensitivity Analysis for Nursery E. The table shows the nursery group, which relates to their revenue (Group 5), the ponds and buffer areas assumed, and the profit per square foot measures. The defender and challenger totals are shown minus the revenue forgone because of recapture or buffer ponds. To find the new outcome of the partial budget, the unit profit is multiplied by the pond and buffer areas, and then added to the defender and challenger respectively. The new partial budget totals can be found by adding the revised costs of storage pond (Defender) or buffer pond (Challenger) to the costs of the option. Tables for each nursery are in Appendix B. For example, the mean/upper profit per square foot from Table 5-4: Operating Profit per Square Feet Sensitivity Analysis for Nursery E, was $0.11. The mean/upper corresponds to the mean for the profit and the upper range for the square feet from the previous tables (Table 5-2: Nursery Operating Profit and Area **by Revenue Category** and Table 5-3: Profit per Square Foot for Differing Nursery **Areas and Operating Profits**). The profit per square foot, $0.11 would be multiplied by the area of the pond and buffer area. The product of multiplying $0.11 by the square foot area of the pond (309,694 ft^2) and the buffer pond (7,421 ft^2) would amount to ($34,066) and ($202) respectively. The Defender without Pond Costs and Challenger without Pond Costs are measures relating to the initial partial budget table of all costs associated with the respective option not including the opportunity cost of the pond or buffer pond. These costs of the defender and challenger not germane to the opportunity cost are assumed to be constant across the different levels of profit per square foot measures. Therefore, as the opportunity costs of the pond areas change they can be added to the assumed constant costs of the rest of the nursery producing a new outcome of the partial budget depending on the new cost per square foot of the land. The baseline is characterized by the mean profit and mean square foot area of the nursery. The pond and buffer amounts can be added to the defender and challenger totals. The new partial budget total would be $127,552 percent change in the estimated difference between the cost of the Defender and that of the Challenger is shown in the next column, A sensitivity index is shown in the following column. Sensitivity Index divides the percent change in the Challenger minus Defender cost difference by the percent change in operating profit per square foot.

Equation 5

$$Sensitivity\ Index = \frac{\frac{[New\ Outcome\ of\ Partial\ Budget - Mean\ Outcome\ of\ Partial\ Budget]}{Mean\ Outcome\ of\ Partial\ Budget}}{\frac{[New\ Profit\ per\ Square\ Foot - Mean\ of\ Profit\ per\ Saquare\ Foot]}{Mean\ of\ Profit\ per\ Square\ Foot}}$$

The sensitivity index shows the responsiveness of the partial budget cost difference to changes in profit per square foot. A number closer to zero indicates less change in the outcome as the profit per square foot varies.

Table 5-4: Operating Profit per Square Feet Sensitivity Analysis for Nursery E

Cost of Land Sensitivity Analysis Table					
Nursery E					
Group	5	Defender without Pond Costs	$120,580	Percent Change from the Baseline	Sensitivity Index
Pond Area	309,694				
Buffer Area	7,421	Challenger without Buffer Costs	$282,697		
Profit / Sq Foot Ranges Combinations	Profit per Sq Ft.	New Outcome of Partial Budget			
Upper/ Upper	$0.13	($122,367)		0.00%	—
Upper/ Mean	$0.15	($116,405)		-4.87%	-0.32
Upper/Lower	$0.18	($108,338)		-11.47%	-0.32
Mean/Upper	$0.11	($127,552)		4.24%	-0.32
Mean/Mean	$0.13	($122,367)		0.00%	—
Mean/Lower	$0.15	($115,352)		-5.73%	-0.32
Lower/Upper	$0.10	($132,737)		8.47%	-0.32
Lower/Mean	$0.11	($128,330)		4.87%	-0.32
Lower/Lower	$0.13	($122,367)		0.00%	—

There were some nurseries that exhibited a large swing between the various partial budget outcomes as operating profit changed. Nursery G, for instance, showed a upwards of a 200% change in the difference in costs between the defender and the challenger for one operating profit per square foot group, group 5. Other nurseries showed almost no change in the partial budget as profit per square foot varied from the initial base line. The results indicate that, unless there are extreme circumstances, such as Nursery G having a small disparity in the difference of the original, or baseline partial budget, the total change in operating profit per square foot will not drastically the difference in costs between the challenger and defender. .

The sensitivity index is characterized as the percentage change in net profit divided by the percentage change in operating profit. The results from each nursery can be found in Table 5-5 below.

Table 5-5: Sensitivity Index for Nurseries with Respect to Operating Profit

Sensitivity Index involving change in the operating profit per square foot (based upon an assumed 15% change from the Mean)					
Nursery	***A***	***B***	***C***	***D***	***E***
Sensitivity Index	N/A	-0.01	-0.09	0.74	-0.32
Nursery	***F***	***G***	***H***	***S Small***	***S Large***
Sensitivity Index	0.20	-17.32	0.11	0.14	1.00

As can be seen by Table 5-5**: Sensitivity Index for Nurseries**; six of the eight case nurseries show between zero and unitary elasticity, with respect to the change in operating profit per square foot. An increase in the operating profit per square foot of 100% would affect the difference between the defender and challenger amounts by the Table 5.5. For example is Nursery D were to increase the operating profit per square foot then the difference between the defender and challenger would increase by 72%. Nursery A has no sensitivity index involving its profit per square foot because the recapture tanks are buried, thus not taking up growing space. As a result, the least-cost water source is not affected by varying unit operating cost in most cases. Nursery G is the only outlier in this group, exhibiting a change in the least-cost option that fluctuated between the defender and challenger options depending on the percentage change in the operating profit per square foot. The least cost option changes because of the similarity between the costs of the two water source options. With a small cost difference between the two water sources, a modest change in one of the input costs causes a large percentage change in the cost difference. The higher the operating profit per square foot and lower the area, the more that partial budgets change, which makes sense as the land becomes more valuable in those options for Nursery G, thus changing the output of the new partial budget outcome. The opportunity costs of the pond are a large portion of the budgets pertaining to Nursery G and any small change in these costs would affect the outcome regarding the difference in costs of water between the defender and the challenger.

Chapter 6 Discussion and Conclusion

Partial budgets show the financial difference between irrigation recapturing and recycling practices in comparison to other irrigation water sources. The budgets consider structures and practices used to recapture water and address undesirable consequences such as pathogen contamination. The partial budgets were constructed using constant 2014 prices. The budgets provide an in-depth analysis of nursery costs associated with recapturing and recycling. Of the eight existing nurseries, it was shown that six would have lower costs with recapturing and recycling irrigation water relative to an alternative source of wells or municipal water. For two of the nurseries, well water or municipal water was a lower cost option.

The results indicate that land regrading and digging of ponds to facilitate water recapture are the highest capital cost items for implementing a recycling irrigation system. The opportunity cost of the land dedicated to a recapture pond represents a large cost of recycling as well. However, it should be noted that the opportunity cost of land is highly dependent on development and land prices of the surrounding area. Water treatment costs for removing pathogens were not large relative to other costs.

Two synthetic nurseries were constructed with the assumption that well water was the defending option. The synthetic budgets showed that well water was a more cost-effective choice due to the large costs associated with regrading.

The regrading costs equal about 50% of the partial budget outlays for nurseries that regraded. Opportunity cost of land devoted to the recapture pond and cost of excavating the recapture pond were also large costs. These items can be seen as the most significant barriers to recapture and recycling of irrigation water. The land set aside for increased water storage comes at a high cost due to foregone revenue for growing plants. Some case nurseries had large capture ponds, over two acres, which allowed for increased reserves of water to be held on the premises. The forgone operating profit of the land occupied by these water reserves indicated the value placed upon such reserves by the growers.

Sensitivity analysis was conducted to show how future price adjustments in land opportunity cost could affect the overall bottom line of the partial budget. The effects of varying water and land costs depend on the initial amount of water and land costs in the recycling budget. Results of the sensitivity analysis indicated that initial findings were robust and not significantly affected by changes in the costs of land or water extraction with the exception of two nurseries for which costs of the defender (recycling) and challenger (municipal water or well water) were nearly equal in the baseline.

Nurseries indicated that they chose to recapture and recycle water because of concerns about water shortages, ethical environmental choices, and the possibility of future regulations. The size and scope of forgone growing area taken up by recapture and recycling ponds indicates the importance of addressing potential water shortages on the case nurseries. While water recycling can present some disease risks, the monetary benefits often outweigh the costs.

If concerns about water availability grow over the next few years, many nursery growers may focus on recapturing and recycling irrigation water to either replace or supplement their current systems. State and/or Federal subsidies could be provided to mitigate the costs of recycling such as recontouring and excavating recapture ponds.

Such improvements might result in increased savings for growers and decreased depletion of water aquifers.

Variations in the cost of extraction did not have a great effect on the outcome of the partial budgets; thus indicating robust results relative to water cost. However, well water might become subject to regulations on groundwater extraction in response to long term future drought, concerns about possible contamination of water tables, or excess extraction by sources dependent on the water table. There are no such regulations at present.

It can be seen through the case studies that profitability associated with recapturing and recycling of irrigation water is highly dependent on the unique physical location of the nursery. The physical location of the nursery determines its proximity to other water sources as well as the maximum water recapture possible on the site. A nursery without access to a cheap and safe source of water should assess the cost-savings which could be obtainable by irrigating with recycled water. Conversely, on nurseries with access to groundwater, the cost associated with water extraction from underground sources may be less than the needed funds for recapture and recycling, depending on the ease of extraction.

Recapturing and recycling irrigation water, even while paying higher pathogen mitigation costs, is profitable for six of the eight case nurseries. Recapture and recycle methods are lower cost in these cases because of the high cost of well water or municipal water alternatives due to distances water must be piped (municipal water) or depth to the groundwater table (well water). As water scarcity problems grow changing the cost of water extraction, it will be important for horticultural businesses, to be flexible regarding choice of water source.

Pathogen mitigation is a relatively small cost compared to other recycling costs if chlorine is used for water treatment. Pathogen control costs may rise in the future if chlorine regulations become stricter or if chlorine is banned. However, even with increased to mitigation costs, these costs are likely to equal the opportunity cost of land, land regrading costs, and pond excavation costs for recapturing and recycling. As seen from results of the partial budgets, the costs of chlorine gas, chlorine injection systems, and other mitigation techniques only amount to approximately 3% for those nurseries that use such techniques. For most operations, it will still be profitable to recapture and recycle, even with increased mitigation costs.

The results of this analysis are specific to eight actual and two synthetic nurseries. These results should be replicated with a larger number of nurseries to provide a more in-depth analysis as to which nursery characteristics tend to make recapturing and recycling the least-cost water source.

Future studies could be conducted with regard to alternative pathogen mitigation techniques for recycling operations. Such analyses should consider economic risks from inadequate pathogen control. Other studies could be focused on regional differences in nurseries that might affect the potential for water recycling. For example, recycling costs relative to alternative water sources for nurseries on the East Coast of the United States, where water is cheaper and more plentiful, could be compared to those for nurseries located in either California or Australia. Additional research should investigate how savings or losses incurred from recapture and recycling affect the economic performance of individual nurseries and the overall industry.

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Appendix A: Case Studies

Nursery A:

Nursery A is located in the Piedmont area of Virginia. To increase recycling of water on the premises, the owner recontoured the entire 2.5 acre pot-in-pot horticultural operation in the 1980s. For this operation it is assumed that city water is available as an irrigation alternative. The city is also assumed to provide irrigation quality water and at a steady rate without any breaks in the line. The city water costs that are accounted for include a hook-up fee as well as the per gallon price of water for augmenting the available supply. The partial budget will be separated into two distinct options; the defenders, relating to recapture/recycling, and the challenger, relating to piping in of municipal water. The defender costs include recontouring the field, stone filters, three water tanks, excavation for water tanks, pumps for irrigation, and gas for the pumps. The challenger option is comprised of a water availability fee, a yearly rate for city water, a water connection, one gas tank to act as a buffer, and a meter service charge. The Partial Budget Table A outlines the costs and how they are related.

Partial Budget Table A

Partial Budget Table: Nursery A				
Defender			Challenger	
Recapture/Recycling of Water			Municipal City Water	
Additional Costs			*Additional Returns*	
Recontouring Field [17]	$1,593		N/A	$ 0
Extra Stone(filters) (4in) [18]	$125			
3 Reused Gas Tanks [19]	$2,682			
Excavation for 2 of the gas tanks [20]	$92			
Reduced Returns			*Reduced Cost*	
N/A	$ 0		Water Availability Fee [21]	$133
			Rate for city water per year [22]	$4,084
			Water Connection [23]	$470
			Meter Service Charge [24]	$900
			1 Reused Gas Tank [25]	$518
Total	$4,493		Total	$6,105
Net Difference		($1,612)		

The water supply must be supplied by either city water or recaptured and recycled water. Each of these options are capable of providing the water for Nursery A. Right now 60-75% of the water used is garnered from wells on the property; indicating that 25-40% of the water must come from municipal water or recycling. Here it is assumed that 33% will come from municipal water or recycling. The partial budget will outline what is needed to install the new, or challenger, water source. Water use for the 2.5 acre nursery

[17] An assumed area of 200 ft. length, 50 ft width, and a 30 ft. depth; the grading area was 370 square yards.
[18] An assumed circle area of a 10 foot radius and the stone imbedded 4 inches down (was the largest depth in the LCB)
[19] Water tanks are new and have a size of about 30,000 cubic feet
[20] Assume that 151 cubic yards needed to be excavated for 2 water tanks at a depth of 12 feet
[21] Onetime Availability Fee for a 1-inch meter
[22] Needed gallons per month, 108900 gallons; used in municipal rate formula
[23] Onetime Fee to connect to the water meter
[24] Yearly total of monthly Fees for meter service
[25] Assume only 1 gas tank used for buffer reserve

ranges between 10,000 and 12,000 gallons a day. Here it is assumed that total use is 11,000 gallons per day. This would mean that 3,663 gallons are needed to complement the output of the existing wells. For the recapture and recycling option, the water was then recaptured and stored in one of three large 10,000 gallon refurbished gas tanks, two of which were buried underground. There was no other filtration or treating of the water, other than the passage through stones imbedded in the ground around the recapture site.

In the case of Nursery A, the main cost item for recycling was remolding the land into a more useable plot for recapture. The entire plot was remodeled from a hill to fulfill two key targets: flatten out the land to maximize the usable land and also contour the land, in a way to maximize the water recapture. The land was flattened and slightly sloped to a center that was filled with stones to aid in the filtration of the recaptured water. The additional costs to the operation coalesce around the restructuring of the nursery to better implement recycling techniques. These are formulated through remodeling, extra stone, reused gas tanks, excavation of gas tanks, pumps, and gasoline.

Remodeling was composed of two different phases of the landscaping. It is assumed that 75,000 cubic feet of earth were moved or manipulated in the process as well as an additional 370 square yards were graded after the process was completed. The numbers associated with these manipulations were found in RSMeans Landscape Cost Manual from 2009[26]. Total costs were converted to 2014 dollars for all calculations to a total of $24,500. Removal of loam or topsoil with stock pile on site was used as a 500 cubic foot haul of soil measure to the remodeling of the 2,778 cubic yards. The regrading of the operation was under the assumption of a fine grade for small irregular areas and used the same LCM to a total of $926. The total remodeling of the plot should take

[26] (Spencer & Babbitt, 2008)

$25,426 in 2014 dollars; using the amortization formula with the interest rates discussed previously, the per year cost of a 30 year amortization is $1,593 for Nursery A.

Along with the remodeling, the owner of the land incorporated rock around the lowest point of recapture to filter recycled water. In regard to the depth of the stone it was assumed to be four inches. For the purposes of the partial budget it is assumed that there was a 10 foot radius of stone around the capture point. The cubic yards of stone needed were gleaned from (LandscapeCalculator, 2014). The total yards of cubic stone needed given the assumptions, 4 inches deep and a 10 foot radius was 3.88. Once again using the LCM [27]the total cost was $1,998 in 2014 dollars, however when amortized for 30 years the total came out to $125.

The use of gas tanks for the recapture and retention of water is a unique idea to this nursery. However, the price of refurbished gas tanks was difficult to properly elicit. Therefore the price from suppliers for a new 10,000 gallon water storage tank for irrigation water is $8,267 per tank (WaterTanks.com, 2014), which does not include shipping costs. On average shipping and delivery charges costs around $6,000 each from tank from the company that was contacted (WaterTanks.com, 2014). Therefore, the cost and shipping of 3 tanks for the nursery would cost $42,800; amortized for 30 years at $2,682 per year. It should be understood that this nursery found reliable, serviceable alternatives to purchasing completely new tanks. The refurbishment of gas tanks for irrigation uses would be decidedly less than the cost of buying these brand new tanks.

Another portion of the operation is that two of the three water tanks are buried underground. It is assumed that around 157 cubic yards would be excavated, based upon the size of the tanks. This entire operation would involve a backhoe and a crane. The

[27] (Spencer & Babbitt, 2008)

former is used to dig out the space and the latter to safely lower the large tanks into the area. The renting of a crane came down to $930; that $930 included travel and a per hour cost , with an estimated job being 6 hours at $155 per hour (Lynchburg Crane, 2014). This value was added to the labor costs associated with work from the LCM to bring the total to $1,307.   This total also must be added to the cost of excavating the holes for the tanks. The size of the tanks was estimated, and then the cost of extraction of that area was estimated in 2014 dollars using the LCM[28]. The total of the excavation was $544. Total of extraction of soil and installation of water tanks was $1,814, which was amortized over 30 years for an annual amount of $92.

There were no reduced returns or additional costs associated with this budget, mainly due to the nature and composition of the nursery. Reduced costs, which correspond to the challenger, are all connected to the use of municipal water for irrigation purposes. As stated previously, there is only the need for 3,630 gallons daily, as a well provides the other portion of the water consumed. The prices for water come from the Western Virginia Water Authority. The price of water corresponds to a water meter size of 1 inch. Water meters are important due to the pricing schedule associated with the varying sizes, such as higher prices for larger meters. A larger meter can accept and record a greater portion of water than a smaller meter. The Western Virginia Water Authority's monthly rate associated with the meter size is $75 per month or $900 per year and rate for water is $5.00 per 1,000 gallons (Western Virginia Water Authority, 2014). Nursery A, it is assumed, would go through 108,900 gallons a month during the summer months. With the lowered rate of ten percent for five winter months, the total usage per year would come to 816,750 gallons. Combining that total with the $5.00 per 1,000

[28] (Spencer & Babbitt, 2008)

gallon charge, gleans a total charge of $4,084 per year. There is also a water connection fee of $7,500, this fee is a onetime expense and amortized over 30 years accounts for $470 per year. The last charge for water is associated with the onetime, water availability fee of $2,130; this fee was amortized over 30 years at the same rate as the other expenditures, to a total of $133. The final cost is the reused gas tank at a rate of $518 taken from the same costs as the three reused gas tanks previously. The total of the reduced costs is $6,105.

The total of all costs for the defender, or recapture/recycling program, is $4,493; while the challenger, relating to the municipal water costs is $6,105. Thus the nursery would have spent an extra $1,612 per year by initially implementing a system of getting water from the municipality.

Discussion for Nursery A:

Nursery A is an interesting case as it was the first nursery visited as this project began. There are a variety of innovations that the owner incorporates to this operation. The biggest being the incorporation of the gas tanks into the irrigation system of the nursery. The repurposed gas tanks were purchased at a bargain, as comparable to the price of new tanks which were found for the budget in the study. The tanks served a key use of maintaining water while decreasing the loss of land and the lost opportunity cost for the farmer to continue to grow crops if a surface pond were used for water storage. The nursery also did not incorporate a large scale filter to sift the water; instead it used a series of stones to act as a natural strainer. The nursery should be analyzed as an inventive way to cut the cost associated with nursery development while reaping the gains of innovative problem solving.

One aspect that the nursery did not part take in was the chlorinization of the water. The chlorine and cost were added to show the costs that would be incurred as a proxy for the losses. It was viewed a reasonable way to mitigate the disease losses for the nursery. Therefore, a comparable nursery could analyze the costs associated with the installation and uses of chlorine with the losses to pathogens to decide how to treat water.

The main cost from analyzing the partial budget was the recontouring of the land to maximize recapture. The entire process of recycling of water reserve is dependent on being able to recapture as much water as possible. Recontouring indicates a large outlay of capital and resources for such a project. This value must be discounted against future increases in the price of water in an area or municipality. For instance, if it is believed that the cost of water will increase by a large amount in the future, recapturing water could prove to be more profitable in the long run. There is also the possibility that fees and charges relating to the water increase in the future as inflation also increases.

Calculations for Nursery A:

Appendix Table 1

Gas Tanks								
Price per tank								
	$8,267							
Price from call was a little over $8,000								
So $8266.54 per tank; need 3 tanks								
	$24,800				1877-655-1100			
Shipping	about $5-7,000 to ship a tank on average depending on where it was fabricated							
	so at around $6000 a tank would be about right, depending on permits and escorts of the load							
	$6,000							
Quantity	3							
	$18,000							
Total for Tanks	$42,800							

Appendix Table 2

Cost of Gas Tank	
Price per Tank	$8,267
Quantity	1.00

Appendix Table 3

Excavation for the tanks			
Gas Tanks			
A = 2(pi)rh + 2(pi)r^2			
10,000 gallon capacity is either			
	1	2	
Length (ft)	26.5	17	
Radius (in)	48	60	
Depth needed to submerge (ft)	8	10	
	need about 10 ft	need about 12 ft	
With extra room (ft)	10	12	
Area=	22468	29028	
Area of 2 tanks	44936	58056	
Area of excavation cubic feet	4240	4080	
Convert to Yards Cubed	157	151	

Appendix Table 4

Excavation												
1000 with 10' to 14'												
1-1/2 C.Y Excavator												
Crew	Equip Cost Bare	Equip Cost	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-12B	54.11	59.53	37.08	56.48	540	0.03	B.C.Y	0	1.1	1.6	2.7	3.43
Quantity Needed												
Area	0.00	Pounds										
Conversation	151.1111	B.C.Y										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
0	540	0										
Labor Hours:	Productivity											
0	0.03	0										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 408												
O&P												
Total O&P * Quantity												
$ 518												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 544												

Appendix Table 5

Backhoe-Large						
Rental Rates						
	4 hours	Daily	Weekly	4 Weeks		
	$340.00	$340.00	$1,200.00	$3,300.00		
Crane Rental to move Gas tanks into hole						
	http://www.lynchburgcrane.com/			Jeff Sheppard		(540) 586-2200
$155.00	per/hr (including travel there)					
	to put in 2 tanks from the truck bed would be about 6 hrs.					
so 155 * 6	$930.00					
Total work	If assuming 2 tanks in the ground delivered and with a crane put in.					Assuming that only takes a day to dig out the ditch
	$1,474.23					

Appendix Table 6

Water Usage						
Using a win 1 inch meter						
Just hooking up water						
In 2014 dollars						
Nursery Uses about 11,000 gallons a day with 1/3 of that coming from recycling other 2/3 from wells						
so would need	3630	gallons a day				
and	108900	a month				
	330000					
Monthly				Irrigation		
2 inch	Minimum usage	Rate 2014	Rate 2015	(per 1,000		
	10,000	$75.00	$75.00	$5.00		
Yearly Rate of water (Meter service charge)						
	$900.00					
Usage	10,000 - 12,000 gal/day			Cost Per Gallon		
	11,000 daily	for a month = 330,000 gall		0.005		
		816,750				
Cost per month for water	$4,083.75					
Yearly water costs	$4,083.75					
Water Availability Fee for 1 inch meter						
	$7,500.00					
Water Connection Fee						
	$2,130.00					

Appendix Table 7

Stone Calculations				
about a 10 ft radius of stone around the filter				
Area in Sq Feet = 314				
from pg 326 Rip-rap Rock lining				
The 49.27 is in 2009 $ and thus must be transferred to 2014 dollars (rate is 1.1				
Cost per load	54.197			
Stone filler				
Depth of stone	Cubic Yard of Stone	Weight for	Tones	
1 inch	0.97	2,619.00	8.7300	
2 inch	1.94	5,238.00	17.4600	
3 inch	2.91	7,857.00	26.1900	
4 inch	3.88	10,476.00	34.9200	

Appendix Table 8

Cost of Embedding stones into ground as a filter												
4 inch Depth												
	Dumped 300 lbs Average rip-rap and rock lining											
Crew	Equip Cost Bare	Equip Cost	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-11A	67.63	74.39	36.48	55.58	600	0.027	Ton	46.5	0.97	1.8	49.27	54.5
Quantity Needed												
Area	34.92	Pounds										
Conversation	34.9200	Ton										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
34.92	600	0.0582										
Labor Hours:	Productivity											
34.92	0.027	0.94284										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 1,721												
O&P												
Total O&P * Quantity												
$ 1,903												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 1,998												

Appendix Table 9

Regrading			ft	Yds								
Assumes length	200	square ft	10000	370.3704								
Depth	15											
Width	50	ft	yards									
Total Area (b*w*h*.5)		75000	2777.777778									
pg 281	1440											
Total Area (b*w*h*.5)		2777.778	cubic yards									
Loam or Topsoil rem	for 500' Haul											
1440												
Crew	Equip Cost Bare	Equip Cost	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-10B	90.17	99.18	38.1	57.77	225	0.053	Cubic Yard	0	2.03	4.81	6.84	8.4
Quantity Needed												
Conversation	2,777.7778	Yards										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
2777.777778	225	12.34568										
Labor Hours:	Productivity											
2777.777778	0.053	147.2222										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 19,000												
O&P												
Total O&P * Quantity												
$ 23,333												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 24,500												

Appendix Table 10

Grading of the slope at the property												
Assuming that the area is 10000 Square yards												
370.3703704	sq yds											
Fine Grade for small irregular areas												
1050												
Crew	Equip Cost Bare	Equip Cost	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-32C	90.17	99.18	38.1	57.77	2000	0.024	Cubic Yard	0	0.88	0.93	1.81	2.38
Quantity Needed												
Conversation	370.3704	Yards										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
370.3703704	2000	0.185185										
Labor Hours:	Productivity											
370.3703704	0.024	8.888889										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 670												
O&P												
Total O&P * Quantity												
$ 881												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 926												

Nursery B:

Nursery B, located in the coastal plains of Virginia, was founded in 1969 as a wholesale supplier, and recently moved into retail. The nursery's transition into retail was precipitated by the financial crisis in 2008. It has expanded to include three growing locations in the surrounding area. The nursery has a large recapture pond that is supplemented by the surrounding ponds that feed into it. The large pond is the point of major irrigation, as the pump house and chlorine system are kept in this area. The land that has been remodeled drains into the catchment pond. The location in question for Nursery B is 100 acres and the owners surmise that 96 acres are recapturing water. The partial budget will be separated into two distinct options: the defender, which relates to recapture and recycling, and the challenger, which relates to the piping in of municipal water. The defender costs include recontouring the field, dredging, a chlorine injection system, chlorine gas, coppers for algae, digging of recapture pond, and the opportunity cost of the pond. The challenger option is comprised of selling off recontoured soil, opportunity cost of the buffer pond, digging of buffer pond, a yearly rate for city water, a water connection, and a meter service charge. The Partial Budget Table B outlines the areas of costs and how they are related.

Partial Budget Table B

Partial Budget Table: Nursery B			
Defender		Challenger	
Recapture/Recycling of Water		Municipal City Water	
Additional Costs		*Additional Returns*	
Recontouring [29]	$157,312	Selling off Recontoured soil[30]	$ 94,387
Dredging[31]	$20,882	Reserve or Buffer Capacity[32]	$ 15,382
Chlorine[33]	$28,000		
Chlorine System[34]	$179		
Copper[35]	$661		
Digging of Recapture Pond[36]	$59,692		
Reduced Returns		*Reduced Cost*	
Opportunity Cost of Pond[37]	$24,597	Hook up of 10' Water Meter[38]	$ 155
		Rate for City water [39]	$ 1,311,497
		Treatment for Public Water[40]	$ 2,233
		Water Availability Charge[41]	$ 38,841
		Meter Service Charge[42]	$ 731
		Digging Buffer Pond[43]	$37,322
Total	$291,322	Total	$ 1,500,548
Net Total	($1,209,226)		

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[29] The recontouring encompassed 100 acres of land with an assumed depth of 2 yards
[30] The nursery sold off the soil from the reshaping and the proceeds paid for 60% of the recontouring
[31] Assumed dredging every 15 years on the entire pond (is based upon square footage of the pond)
[32] The reserve proportion of the buffer pond was found by comparing the needed reserves and the capacity currently
[33] The cost of chlorine was found by assuming overall water used per year and the 2 ppm chlorine needed for pathogen mitigation
[34] The chlorine system is used to inject chlorine gas into the water passing through for irrigation purposes
[35] Coppers are used in a 3 week capacity throughout the summer
[36] Assume digging out 187,041 square feet of area
[37] Costs relating to the forgone growing area the pond takes on
[38] Cost of installing a 10' water meter (no price was listed on the municipal site but assumptive estimations were made)
[39] The rate for municipal water given the usages per year
[40] Cost of a filter to control the fluctuations in the water to maximize effectiveness of irrigation water
[41] Onetime fee that was amortized over 30 years; for the access to such a large amount of water
[42] Monthly service charge for the water meter
[43] Assume digging out 116,970 square feet of area

A major problem with the operation is the lack of availability of water. The wells in the area do not produce water suitable for agriculture uses due to iron and sodium bicarbonate contamination. To resolve this problem, the business began using water from the local municipality. However, this caused other issues to arise. The municipal option was also dubious, as the water pH level fluctuated at times. Owners of the nursery looked to other avenues to gain the water needed to sustain the operation. To this end, they began to restructure their operation to get the most recaptured water possible. It will be assumed in this partial budget that the alternative water supply is the municipal option; its infrastructure is already in place. There will be the addition of a filter to augment this decision and make the water applicable to the nursery plants.

The operation requires one million gallons of water per day to function in the warm months of the growing season. If Nursery B were to get its water from the municipality, we are assuming a 10-inch water meter would be needed**.** It is assumed that the municipality has the requisite amount of water and the ability to sell the water to Nursery B for this example. A 10 inch water meter would provide 3,500 gallons per minute (gpm), and over 6 hours would exceed the one million gallons per day (DC Water Authority, 2004). There are installation and service charges that must be accounted for when costing out the total. The city water hook-up fee is $2,468, and is a onetime payment that is amortized over thirty years to a total of $155 per year. The water availability charge is a onetime cost of $619,850 that was amortized over thirty years to a total of $38,841 (City of Norfolk Utilies, 2014). Nursery B has already used city water in the past; therefore we will assume the water connection fee will not be applicable. However, the meter service charge for a 10-inch meter will still be active, at a rate of

$730 yearly[44]. These are all the fees and costs associated with the installation of the meter to obtain access to city water. The actual price of water is $4.36 per 100 cubic feet[45]. A cubic foot refers to 7.48 gallons, thus 100 cubic feet would be equivalent to 748 gallons. With a usage of one million gallons, there are 1336.89 CCF (hundred feet of cubic water) during the warm growing months, thus the total daily price of water would be $5,828. The yearly amount would consist of seven months of water use for warm growing conditions and five months of water use for growing at diminished rate. There would be a total of 225,000,000 gallons used annually. Therefore, the yearly cost would amount to $1,311,497. This assumes that the peak of one million gallons a day is used annually during the summer. The initial problem with the municipal water policy was the usage of the water as the pH fluctuated. To solve this, they would need a filter from Forsta Filters Inc., which includes a pH regulator that can sift 3500 gpm at a cost of $25,000 (Forsta Filters, 2014). If that amount is amortized over a period of fifteen years, this indicates a payment per year of $2,233.

The reshaping of the operation is a major contributor to the sustainability of Nursery B without the use of wells or municipal water. The LCM[46] has all of the metrics in cubic yards for these calculations. It is assumed that not all of the land re-contoured, as part of it is well graded and slightly sloping. We assumed that 100 acres were recontoured at 2 yard depth across the span. The removal and stock piling of soil for the needed area is a cost of $2,063,292. The nursery had all equipment needed for the recontouring available in-house; thus, the costs were minimized. The grading of an area of 100 acres, or 484,000 square yards, costs $447,216. Using the LCB, the total comes to

[44] (City of Norfolk Utilies, 2014)
[45] (City of Norfolk Utilies, 2014)
[46] (Spencer & Babbitt, 2008)

$2,510,508 for both recontouring and grading of the property. The total was amortized over thirty years, meaning that the yearly cost is $157,312.

A major problem of a recycling operation is that water can become subject to large algal blooms. The uses of coppers are employed, assuming that they will only be used for twenty-six weeks at the times when the algal blooms would be most prevalent. Costs of copper are $40 per gallon. Using Daft logic area calculation maps to estimate the size of the water masses, a rough estimate was gained of 4.29 acres (Daftlogic, 2014). Therefore, depending on the frequency of the treatments, the costs associated with both can be gleaned. The use frequency of every three weeks would come out to a price of $661 per growing season.

Nursery B uses a chlorination system to mitigate the risks associated with certain diseases and water borne illnesses related to growing plants. The nursery uses only a chlorination system, which costs $2,000 and lasts fifteen years according to Regal Chlorinators (Regal Chlorinators, 2014). Amortization of these costs comes to $179 annually. The other cost associated with this mitigation technique would be the actual purchase of the chlorine gas itself. The total chlorine needed relates back to a Fisher (2013) article that relates to 2ppm needed for the water used in irrigation. Thus the total amount of water used by the nursery is directly related to the needed chlorine. The nursery consumes 3,750 lbs according to the needed amount for 2ppm, and thus would require twenty-five cylinders which contain 150 lbs each. The cost of such a cylinder is $1,120 per unit for a rental (Advanced Specialty Gases, 2014). In conclusion, the total cost of chlorine would be $1,120 multiplied by the twenty-five cylinders, reaching a total of $28,000 per year.

The dredging of the pond comes at a cost of $233,802 and would occur every fifteen years. The cost of dredging comes from the rule of thumb used for $1.25 per square foot, and from an 187,041 square foot pond comes to $233,802. Therefore, the annual cost of the dredging would amount to $20,882 when amortized over fifteen years (Donahoe, 2015). The digging of the pond was also a large outlay with the average, for digging out 187,041 square feet, at $952,611 (Homewyse, 2015). Annual total would be $59,692 for the pond.

There would be an opportunity cost associated with the area that the pond occupies. This cost is in relation to the forgone profit from plants that could have been grown in that area. The total square footage of Nursery B's pond is 187,041 square feet. Multiplying that number by the ordinal mean range of profit per square foot at $0.13[47], the total forgone profit is $24,597. These numbers are related back to the methodology section that outlined the way in which the groups were selected. From the total, it can be assumed that the nursery loses $24,597 of profit from the space the pond occupies.

The additional returns for the nursery relate to the selling of the re-contoured soil for a profit. The nursery indicated that the soil was sold off and covered 60% of the total cost relating to the overall recontouring. Therefore, the total recontouring cost was multiplied by .6 to elicit the 60% that was covered by the selling of topsoil. Thus the total re-contouring cost was $2,510,508, and 60% of that is $1,506,305. That total was amortized over thirty years (like the re-contouring) to an annual total profit for the nursery of $94,387. There is also the forgone profit for the area consisting of the buffer pond . The forgone profit is directly related to the proportion of the available capacity to the capacity needed for seven days of watering. That proportion is then multiplied by the

[47] From Calculations regarding to the Cultice Survey results (2013)

forgone profit per square foot to get the opportunity cost of land committed to the buffer pond.

The buffer pond consists of an area where the nursery can pool water for future irrigation. The cost of the buffer ponds in terms of forgone opportunity costs is $15,382 for Nursery B. This number is found by using a proportion of needed reserves being divided by the known capacity. The proportion for Nursery B is .625[48]. That number is then multiplied by the opportunity cost of the initial pond to get the value of the buffer pond. The final additional cost is related directly to the buffer pond. If the nursery moves from the larger pond to the smaller one, the difference in space must be filled in with earth to allow for growing of plants. This was calculated by using the other part of the proportion previously stated in the methodology, or 1 minus the proportion, to get the area that needs to be filled in by a hypothetical buffer pond. A variant of the initial proportion was multiplied by the square footage of the current pond to find the area that would be lost to the reclamation of growing space. The digging of a buffer pond is an important item for the nursery to realize. The total of digging a pond would be $595,619, according to (Homewyse, 2015) and 116,970 square foot area. Annual total, over thirty years would be $37,322.

The total of all costs for the defender, or recapture/recycling program, is $291,322 while the challenger (relating to the municipal water costs) is $1,500,548. Thus, the nursery has saved $1,209,226 annually by initialing implementing a recapturing and recycling irrigation system.

<u>Discussion for Nursery B:</u>

[48] See Appendix C for Proportion Table

Nursery B is a great example of a detail oriented nursery pivoting from a municipal water nursery to a recapture/recycling nursery after a variety of factors pushed it into such a state. When initially starting out, the operation used municipal water but soon realized that the water from the city was not meeting the standards needed for horticulture irrigation. Therefore, the nursery took matters into its own hands and began to assess the applicability of reshaping the nursery for recapture. There were a variety of factors that went into the decision, but from talking to the owner, it seems the main concern was control over their own water source.

The owner of the nursery indicated that he received financial assistance from the government for the reshaping of the nursery. There was also the selling of the topsoil to mitigate the overall cost of the reshaping. The lesson to be taken from the Nursery B is that there are ways to mitigate the costs associated with reshaping, if the reshaping is necessary for the survival of the nursery. The operation used a variety of interesting options to cut costs using inventive means; most notably, the use of a refurbished train tankard in lieu of a pressure tank for the irrigation system.

It can be seen that the price for water is much higher in this case than the previous nursery. One could assume that the size of the nursery has a direct effect on the ability to engage in profitable recapturing and recycling of the nursery. However, there is a direct correlation to the amount of chlorine needed as the size in gallons increases, this can be attributed to the recommended 2ppm from Paul Fisher (Fischer, 2013). There is also a large output from the dredging of the pond as indicated by the size of the pond and need to keep particulates from settling and occupying space that could be used for capturing water.

In conclusion, Nursery B shows how it can be profitable for a large scale nursery to pivot back to a recapture/recycling philosophy. The decision was made for the future life of the nursery. As indicated by the owner, the nursery would not have survived without control over its own source of water. The nursery is now highly profitable and recently expanded from a strictly wholesale operation to one that also caterers to the retail consumers.

Calculations for Nursery B:

Appendix Table 11

Assuming 10 inch water meter		
Water Availability Charge		
$619,850.00		
Meter Service Charge		
$730.85		(Monthly)
WTWA Wholesale Water Rate		
$4.36	per 100 cubic feet	
Usages (gallons)		price per gallon
1,000,000		0.0058289
1 CCF (100 cubic feet) = 748 gallons		
30000000	Monthly uses (hot months)	
1336.898396	CCF	
$5,828.88	Daily Cost of Getting Water	
$174,866.31	Monthly Costs (30 Days)	
$1,311,497.33	Yearly Costs	
Water Connection Charge		
a 2 inch meter is		
	1975	
*There is no listed meter size for the 10 inch water meter that is assumed in this example		
**Therefore talking to the municipality the possibility of the using a 10 water meter is a function of the site and location and could be as much as the 2 inch or greater		
***It will be assumed that there will be no difference in the price of installing a 10" water meter than the 2" counterpart, as everything else remain constant.		
****The price list indicated that "When the size is above those listed a charge equal to actual cost of installation plus 25%" will be incurred		
Price of 2"	1975	
Price for 10"	2468.75	Estimated cost based on assumptions.

Appendix Table 12

Water filter for pH	
Info from forsta filters inc, on a 3,500 gpm filter to regulate the pH in water	
cost	$25,000

Appendix Table 13

Chlorine Systems	
System for chlorination	$2,000.00
Smart-Valve	$7,500.00
Chlorine Gas Detector	$2,000.00

Appendix Table 14

Coppers		
Use for 1.5 acres foot of water per gallon		
Acres are 4.13 size of lake		
	2.75333333	
Use every 1 to 2 weeks		
with 12 weeks of summer		
and needing 2 gallons per spreading		
Costs per gallon		
	$40.00	
Per treatment	$110.13	
Once per week costs		
	$1,321.60	
Every 2 weeks		
	$660.80	
*Assuming using Coppers every 2 weeks		

Appendix Table 15

Cost of Chlorine				
in 2014 dollars				
Gas Price (per cylinder)			$575.00	
Cylinder Price			$250.00	
Cylinder Rental option (per month/ per cylinc			$12.50	
Freight (375+20 hazmat fee)			$395.00	
Total (per cylinder)			$1,220.00	
Total (per cylinder) (12 mon. rental)			$1,120.00	
Uses 3750 lbs per year according to 2ppm for their water uses				
Avg	3750			
Tank contains	150			
	25			
So need 15 canisters	25			
will assume rental per cylinder				
Total cost for Chlorine	$28,000.00			

Appendix Table 16

Dredging				
Assume it costs $1.25 per square foot				
$ 1.25				
Estimated square footage of the ponds based on daftlogic area tool				
Square footage				
187041.28				
$ 233,802				

Appendix Table 17

Soil Sell off					
Soil Sell off				Total Regrading Amount	
Amount of soil displaced			$2,510,508		
35,852	cubic feet		0.6		
Price per cubic foot of topsoil			$ 1,506,305		
2.67					

Appendix Table 18

Regrading												
egrading 100 acres of farm lar												
Fine Grade, for p	for 500' Haul											
50 ft down	100	Acres	Depth									
pg 281			2									
*assume 30 acre	484000	square yds										
Loam or Topsoil	for 500' Haul											
Total Area (b*w*h*.5)		968000	cubic yards									
Loam or Topsoil	for 500' Haul											
1440												
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-10B	90.17	99.18	38.1	57.77	225	0.053	Cubic Yard	0	2.03	4.81	6.84	8.4
Quantity Needed										Total for in house		
Conversation	968,000	Yards								2.03		
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
968000	225	4302.22222										
Labor Hours:	Productivity											
968000	0.053	51304										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 1,965,040												
O&P												
Total O&P * Quantity												
$ 1,965,040												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 2,063,292												

Appendix Table 19

Grading of the slope at the property												
Assuming that the area is 484,000 Square feet												
Fine Grade for small irregular areas												
1050												
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-32C	90.17	99.18	38.1	57.77	2000	0.024	Cubic Yard	0	0.88	0.93	1.81	2.38
Quantity Needed										Total for in house		
Conversation	484,000	Yards								0.88		
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
484000	2000	242										
Labor Hours:	Productivity											
484000	0.024	11616										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 425,920												
O&P												
Total O&P * Quantity												
$ 425,920												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 447,216												

Nursery C:

Nursery C is an operation located in the coastal plains of Virginia, that was founded with the expressed idea to implement a recapture recycle model of irrigation. The business started in 1999 and has 400 acres, 200 of which are in production. Two thirds of the property was purchased from adjacent farm land. The partial budget will be separated into two distinct options; the defenders, relating to recapture/recycling, and the challenger, relating to piping in of municipal water. The defender costs encapsulate recontouring the field, dredging, chlorine injection system, chlorine gas, a low fountain, a bubbler, digging of the recapture pond, and the opportunity cost of the pond. The challenger option is comprised of selling off recontoured soil, the opportunity cost of the buffer pond, digging of the buffer pond, a yearly rate for city water, a water connection fee, the installation of the water pipes, and the engineering, fees, and permits related to the installation of the water pipes. The Partial Budget Table C outlines the areas of costs and how they are related.

Partial Budget Table C

Partial Budget Table: Nursery C			
Defender		Challenger	
Recapture/Recycling of Water		Municipal City Water	
Additional Costs		*Additional Returns*	
Recontouring Fields [49]	$315,833	Selling off Recontoured soil[50]	$ 252,667
Dredging[51]	$179	Reserve or Buffer Capacity[52]	$ 8,790
Chlorine systems[53]	$1,822		
Chlorine Gas[54]	$16,800		
Low Fountain[55]	$234		
Bubbler[56]	$854		
Digging of Recapture Pond[57]	$279,165		
Reduced Returns		*Reduced Cost*	
Opportunity Cost of the Pond[58]	$115,058	Rate for city water [59]	$ 652,550
		Water Meter 10" Install[60]	$ 7,143
		Connection Fee[61]	$ 2,381
		Installation of Water pipes[62]	$ 61,400
		Engineering, Fees, Permits[63]	$ 248,100
		Digging of Buffer Pond[64]	$11,059
Total	$729,945	Total	$ 2,500,395
	Net Total	($514,185)	

[49] Assumed 200 acres were recontoured with a depth of 5 yards
[50] The selling off of the soil was indicated to account for 80% of the recontouring
[51] Assumed dredging every 15 years on the entire pond (is based upon square footage of the pond)
[52] The reserve proportion of the buffer pond was found by comparing the needed reserves and the capacity currently
[53] The chlorine system is used to inject chlorine gas into the water passing through for irrigation purposes
[54] Cost was indicated by the volume with which the nursery goes through on a yearly basis
[55] Is used to aerate the pond
[56] Also used to aerate the pond
[57] Assume digging of an 874,937 square foot area
[58] Costs relating to the forgone growing area the pond takes on
[59] The rate for municipal water given the usages per year
[60] Onetime cost of installing a 10' water meter
[61] Onetime fee for connection to the city water system
[62] Cost of 5 miles of installation of water pipes to give the nursery access to irrigation water
[63] Other bureaucratic costs associated with the installation of a water pipe
[64] Assuming digging of an 34,658 square foot area

After the purchase was complete the entire property was recontoured to maximize the amount of recapture possible. A large trench was dug out around the whole property to facilitate the most recapture. The moat or trench is 10 to 12 feet deep and 10 to 12 feet wide. The soil from all of the recontouring was sold to help mitigate the costs associated with the entire construction of the business. By recontouring the land, Nursery C attempts to get water from local sources; farms, streets, or adjacent property.

It should be noted that when the recontouring was done, it was completed with the labor and machinery owned by the nursery. This significantly cut down the costs associated with the manipulation of the land. The top soil was also sold off and the proceeds almost covered the entire costs of the recontouring. These numbers will be explained after the partial budget table.

There is no readily available supplemental option for the nursery due to the lack of municipal water or underground water for the wells. When a drought occurred 2006, the Nursery C had to acquire 25 million gallons from a local farm. To mitigate the possibility of that occurring again, the pond on the property was dredged an extra 9 feet. This study will assume that the next available water source will come from the municipal water supply. Even though the municipal water line is 5 miles away it is still the best option given the infeasibility of hauling in tankers of water, as well as current conditions of surrounding wells.

The reserves of Nursery C are 70 million gallons in the large pond; with another 10 to 20 million gallons stored around the property. The annual usage of the nursery is 90 million gallons. This large capacity is necessary because the nursery uses about 1 million gallons daily. Water is lost in a variety of ways, evaporation could possibly account for as much as 25% of water losses due to the large surface area of the pond. Wind can also reduce the amount of water getting to the plants so wind breaks were planted to stop wind from getting into the facility and disrupting the irrigation.

The recontouring of the fields is a major endeavor at this nursery and is one of the things that makes it unique. It is assumed that the 200 acres of land, as stipulated by the owner, would need to be recontoured to make the recapture system get an efficient return of water. That would mean 1,936,000 total cubic yard of earth were moved, if a depth of 2 yards is assumed. Using the LCB[65], the total costs of the recontouring in terms of removal and piling of soil were estimated to be $4,126,584. The fine grading of the land is assumed to be over 968,000 square feet, which comes to a cost of $894,432. Another unique part of the nursery was the large trench dug around the perimeter of the grounds to aid in capturing excess runoff. The trench is assumed to be 3000 meters, or 3,281 yards, around the property. With the target excavation dimensions at 12 feet by 12 feet, depth and width respectively, the total needed soil excavation would be 52,493 cubic yards. Using a 3.5 cubic yard excavator for a 10 foot to 14 foot deep trench the total cost would be $19,291. The total for the entire recontouring is $5,040,307. To reiterate this assumes that all the equipment was present for the nursery to do the work on an in house basis. The savings were substantial, and in the millions of dollars, as only equipment were used as a cost variable for this nursery. If amortized over 30 years, the total would come to an annual total of $315,833.

The soil that was extracted due to the reformation was later sold off at $25 per cubic yard (Lowes, 2015)[66], but the owner did not know the exact amount of square feet

[65](Spencer & Babbitt, 2008)
[66] Price of similar product in current prices

that was sold off. Assuming that a large portion of the top soil was used in the recontouring of the property, and the rest was sold off, this would indicate that the value associated with the square yards moved is not equal to the total that was sold off. The owner did stipulate that "[The soil] did pay for most of the ground work that was done". With that knowledge it will be assumed that 80% of the costs associated with the recontouring were covered by the sale of topsoil[67]. This will also be amortized over the 30 year period as the soil was not all sold at one time. Therefore, the 80% resale will keep the selling and recontouring as close as possible. The total cost of recontouring, as stated previously, was $5,040,307. Assuming the soil covered the cost of 80% of that total means that the selling of the soil netted Nursery C $4,032,246. Amortization of this sum over 30 years, at the same rate as the recontouring, estimates the annual additional return at $252,667.

The bubblers, or agitators, are a large part of the strategy to combat algal growth in the nursery's ponds. There are eight bubblers used on the property to stymie the algal blooms by putting more oxygen into the water. The assumed cost of these bubblers is $1,195 (The Pond Report, 2014) and it is assumed to have a life of 15 years. The total cost of all eight bubblers is $9,560, and with the amortization over life of the unit the annual total is $854. The low fountain is another strategy used by this nursery to aerate the pond water. There is only one fountain use on the property and it helps to keep water moving within the pond to aerate the water. The low fountain comes to a price of $1,969; this cost was amortized over 10 years to an annual total of $234 (Scott Aerator, 2015). The cost of dredging the pond was $2,000 and has not been done frequently since

[67] From Nursery Visit

the operation has opened for business. Therefore, it will be assumed that the cost will be amortized over a 15 year period.   The annual cost for dredging will be $179.

The technology for mitigating waterborne disease is chlorination. Nursery C has an advanced chlorination system with many high end parts retailing at $5,100. However, due to the large nature of the property and the vast amount of water used daily, the nursery incorporated four separate units to a total of $20,400.   Assuming that the life of a unit is 15 years, the annual costs for all four units is $1,822. The other aspect of this calculation has to do with the cost of the actual chlorine gas as an input into the chlorination system. The cost of chlorine gas is a factor of two features; the gas itself and also the price to rent the cylinder. It is assumed that the cost of chlorine gas and a rented cylinder is $1,120[68]. Nursery C uses between 2000 and 2300 lbs. of chlorine per year, meaning that they would need about 15, 150 lbs cylinders. The total cost yearly for the chlorine and cylinders is $16,800 at a price of $1,120 per unit.

The ponds located at nursery C are large in relation to the daily uses of irrigation water. The area of the ponds is 874,937 square feet which is a little over 20 acres. This area, if filled in could account for a considerable growing area for the nursery. Finding the opportunity cost of that area was accomplished using the technique outlined in the methodology. The profit per square foot was $0.13[69] for similar nurseries in the 7-12 grouping, thus the total opportunity cost was $115,058. The digging of the capture pond would encompass 874,937 square feet area and cost an average of $4,455,129 (Homewyse, 2015); with an annual rate of $279,165.

[68] (Advanced Specialty Gases, 2014)
[69] From Calculations regarding to the Cultice Survey results (2013)

The buffer pond as indicated within the methodology is an important point for the nursery to have a stock of water readily available for use in case of emergency. The pond is directly related to the uses of a normal day and the proportion, as indicated previously, relates back to the initial cost of the pond with regard to lost growing area. A proportion was created by dividing the needed capacity of nursery by the current capacity to get a value of .076[70]; that proportion was then multiplied by the value of forgone profit, $115,058, to get the value of the buffer pond. The opportunity cost of the buffer pond is thus $8,790 of annual lost growing space. The digging of a buffer pond would encompass an area of $3,851 square feet. Capital cost for the dig would be $176,493 altogether (Homewyse, 2015), with an annual total of $11,059.

The other costs associated with the challenger option would be related to the piping in of municipal water as an alternative source of irrigation. Unlike Nursery B there is no assumed water connection in the form of pipes or water meter available for Nursery C. It is assumed that the municipality has the requisite amount of water and ability to sell the water to Nursery C for this example. The costs relating to the water meter installation and connection fee were found from the municipality engineering department. There were no prices listed for a 10-inch water meter, however, the experts at the municipality indicated that the cost would be similar if not the same to their current largest sized meters (Hatcher, 2014; Isle of Wight Utilies, 2014). The prices elicited for the water meter installation and the connection fee were $114,000 and $38,000 respectively. Those prices were each amortized over a period of 30 years. The annual payment for the meter connection is $7,143 and the payment for the water connection is $2,381.

[70] See Appendix C for Proportion Table

As this nursery has never had water utility installed there must be pipes laid for the nursery to receive the hypothetical irrigation source. The laying of pipes it is assumed will encounter no undue problems and go over flat ground with no permit or zoning issues. It is assumed that the distance the water pipes will travel will be 5 miles. The figures were gleaned from the LCM[71] as they pertain to the water pipe installation, digging of the trench for the water pipes, and backfilling the water pipe trench. The water pipes are calculated in linear feet assuming that 5 miles or 26,300 feet of piping was needed in the example. The installation and materials associated with such an enterprise amount to a total of $888,927. The trench, of equal distance, must also be dug out at a depth of 4" to 6" displacing 7,305 cubic yards of earth, costing $27,077. Likewise the backfilling of the trench cost $63,860. Thus, the total amount of the water pipe installation was $979,863; which when amortized over 30 years comes to $61,400 yearly.

Another aspect of the water pipe installation is the engineering, permits, and other fees associated with such an endeavor. According to an expert who has worked in Development and Planning for multiple decades the best rule of thumb is that all other costs pertaining to engineering, permits, and other fees amount to $150 per foot (Kennedy, 2015). Therefore, 5 miles or 26,400 feet, amount to $3,960,000; which when amortized is $248,140.

The actual cost of water in terms of a gallon amount per year is $652,550. This is under the assumption that nursery pumps 90,000,000 gallons per year. This number is gleaned through the nurseries uses of 400,000 gallons per day and then extrapolated out through the growing season and non-growing months, as indicated in the methodology.

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[71] (Spencer & Babbitt, 2008)

The rate for city water is $8.25 per 1,000 gallon for the first 50,000 and $7.25 per 1,000 for any water after that rate (Isle of Wight Utilies, 2014). Thus, the overall cost is $652,550 annually.

The total of all costs for the defender, or recapture/recycling program, is $729,945; while the challenger, relating to the municipal water costs is $1,244,130. Thus the nursery has saved $514,185 by initially implementing a recapturing and recycling irrigation system.

Discussion for Nursery C:

Nursery C is an operation that came into existence due to a large pre-planned initiative. A 400 acre tract of land was bought and recontoured to a master plan that would maximize the recapture of irrigation water. This operation was planned and built specifically with the business plan of water recycling in mind and differs from nurseries in the study due to the defined nature and rigor of the implementation plan. The land was already very arable as it was used for farming previously.

The nursery has immense reserves with regard to their pond size. This could be a factor pertaining to the lack of any other available alternative of water for the nursery. The nursery is located in such an area as they would not have any other feasible option other than the use of recycling. A large problem has to do with the daily water usages needed for the sustained horticulture growing. The nursery did run out of water during one drought season; this lack of irrigation water led the nursery to redredge the pond and create larger overall reserves. Given the high costs of an alternative source of water relative to recycling, it is unlikely that the nursery would be able to survive in the horticulture industry without recycling.

The opportunity cost as it pertains to the land use was an interesting factor with regard to this nursery. The operation had a large amount of excess land available to itself as the nursery operation only used about 200 of the 400 acres of land. This indicated that the value which it places upon the space used for the pond is far less than if the nursery was more rigidly constrained by available growing land.

Overall the nursery is profitable due to its discipline and commitment to the plan of recapturing and recycling water. This should be an example of excellent use of planning and manipulation of land to make a profitable nursery from an area with limited access to water.

Calculations for Nursery C:

Appendix Table 20

Dredging			
Cost	$2,000		
Done only once since the nurseries inception.			

Appendix Table 21

Chlorine Systems		
Costs	$	5,100.00
Quantity		4
Total	$	20,400.00

Appendix Table 22

Cost of Chlorine				
in 2014 dollars				
Gas Price (per cylinder)			$575.00	
Cylinder Price			$250.00	
Cylinder Rental option (per month/ per cylinder			$12.50	
Freight (375+20 hazmat fee)			$395.00	
Total (per cylinder)			$1,220.00	
Total (per cylinder) (12 mon. rental)			$1,120.00	
Uses 2000 to 2300 lbs per year				
Avg	2150			
Tank contains	150			
	14.33333333			
So need 15 canisters	15			
will assume rental per cylinder				
Total cost for Chlorine	$16,800.00			

Appendix Table 23

Bubbler	
Quantity on nursery	
8	
Cost	
1,195	
Total costs	
9,560	
Life of unit	15

Appendix Table 24

Water	
Pump 90 million gallons a year	
Cost per 1000 for first 50,000	
8.25	
50,000	Gallons
413	Total for first 50,000
costs is 7.25 per 1000 gallons at a usage over 50,001	
gallons per year	90,000,000
Gallons per 5000:	89,950,000
scale for cost	1000
total gallon/cost	89950
rate	7.25
total costs	$ 652,550.00
Gallons per day	400,000

Appendix Table 25

Soil Resale	
Assume 80%	0.8
cost of Regrading	
$5,040,307.34	2009 dollars
80% cost	
$4,032,245.87	

Appendix Table 26

Low Fountain
Cost
$ 1,969.00

Appendix Table 27

Water Meter Installation						
Water Meter Installation Charge						
a 4 inch meter is						
	114000					
*There is no listed meter size for the 10 inch water meter that is assumed in this example						
**Therefore talking to the municipality the possibility of the using a 10 water meter is a function of the site and location and could be as much as the 4 inch or greater						
***It will be assumed that there will be no difference in the price of installing a 10" water meter than the 4" counterpart, as everything else remain constant.						
Price of 4"	114000					
Price for 10"	114000	Estimated cost based on assumptions.				

Appendix Table 28

Connection Fee		
Water Connection Charge		
a 2 inch meter is		
	38000	
*There is no listed meter size for the 10 inch water meter that is assumed in this example		
**Therefore talking to the municipality the possibility of the using a 10 water meter is a function of the site and location and could be as much as the 2 inch or greater		
***It will be assumed that there will be no difference in the price of installing a 10" water meter than the 2" counterpart, as everything else remain constant.		
Price of 2"	38000	
Price for 10"	38000	Estimated cost based on assumptions.
*There is no way to understand the costs associated with the installation of the a 10" without actually undertaking that endeavor		
**The master meter would determine the price but since this is a hypothetical problem there is no definitive way to get the number		

Appendix Table 29

Regrading 200 acres of farm land												
Fine Grade, for pa	for 500' Haul											
3 ft down	200	Acres										
pg 281												
200acres =	968000	sq yards										
at 5 yd down need												
	1936000	cubic yards										
Total Area		1936000										
Loam or Topsoil r	for 500' Haul											
1440												
Crew	Equip Cost Bare	Equip Cost	Crew Cost	Crew Cost	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-10B	90.17	99.18	38.1	57.77	225	0.053	Cubic Yar	0	2.03	4.81	6.84	8.4
Quantity Needed										Total for in house		
Conversation	1,936,000	Yards								2.03		
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
1936000	225	8604.44										
Labor Hours:	Productivity											
1936000	0.053	102608										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 3,930,080												
O&P												
Total O&P * Quantity												
$ 3,930,080												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 4,126,584												

Appendix Table 30

Grading of the slope at the property
Grading of the slope at the property
pg 281
Assuming that the area is 968,000 Square Yards
Fine Grade for small irregular areas
1050

Crew	Equip Cost Bare	Equip Cost	Crew Cost	Crew Cost	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-32C	90.17	99.18	38.1	57.77	2000	0.024	Square Ya	0	0.88	0.93	1.81	2.38
Quantity Needed										Total for in house		
Conversation	968,000	Yards								0.88		
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
968000	2000	484										
Labor Hours:	Productivity											
968000	0.024	23232										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 851,840												
O&P												
Total O&P * Quantity												
$ 851,840												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 894,432												

Appendix Table 31

Digging of the trench
3000 meter trench around the property
3280.84 yards with 12' by 12' foot trench
52493.44 total cubic yards to excavate
pg 283

10' to 14' deep 3.5 c.y. excavator

Crew	Equip Cost Bare	Equip Cost	Crew Cost	Crew Cost	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-13F	142.21	156.43	37.08	56.48	1692	0.009	B. Cubic Y	0	0.35	1.35	1.7	2.01
Quantity Needed										Total for in house		
Conversation	52,493.4400	Yards								0.35		
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
52493.44	1692	31.0245										
Labor Hours:	Productivity											
52493.44	0.009	472.441										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 18,373												
O&P												
Total O&P * Quantity												
$ 18,373												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 19,291												

Appendix Table 32

ASSUME THAT WELLS ARE 5MILE AWAY												
Water Pipes												
4560	12 " Diameter	Pressure Pipe class 150, SDR 18, AWWA C900										
Crew	Equip Cost Bare	Equip Cost	Crew Cost	Crew Cost	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-20A	0	0	38.24	58.2	186	0.172	Linear Fee	17.25	6.6	0	23.85	29
Quantity Needed												
Length	26300	Feet										
Conversation	26300	Linear Feet										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
26300	186	141.398										
Labor Hours:	Productivity											
26300	0.172	4523.6										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 627,255												
O&P												
Total O&P * Quantity												
$ 762,700												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 800,835												
Inflation between 2009 to 2014												
$ 888,927												

Appendix Table 33

Trench for Municipal Pipes												
5120	1-1/2 C.Y. Excavato	Digging of Trench for Municipal Pipe at 4' to 6'										
Digging for a 12" pipe												
Crew	Equip Cost Bare	Equip Cost	Crew Cost	Crew Cost	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-12B	54.11	59.52	37.08	56.48	583	0.027	Cubic Yar	0	1.02	1.48	2.5	3.18
Quantity Needed												
Length	26300	Miles										
Width(Pipe Size f	1.5											
Depth	5	5' b/c in-between 4' and 6'										
Conversation	7305.555556	Cubic Yards										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
7305.555556	583	12.531										
Labor Hours:	Productivity											
7305.555556	0.027	197.25										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 18,264												
O&P												
Total O&P * Quantity												
$ 23,232												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 24,393												
Inflation between 2009 to 2014												
$ 27,077												

Appendix Table 34

Backfill of Trench												
3100	Backfill Trench with F.E. loader, wheel mtd, with 2-1/4 C.Y. bucket											
Filling in 5' deep trench with 12" municipal water pipe laid in for 5 miles												
Crew	Equip Cost Bare	Equip Cost	Crew Cost	Crew Cost	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-10T	32.98	36.28	38.1	57.77	150	0.08	Loose Cul	0	3.05	2.64	5.69	7.5
Quantity Needed												
Length	26300	Feet										
Width(Pipe Size f	1.5											
Depth	5	5' b/c in-between 4' and 6'										
Conversation	7305.555556	Cubic Yards										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
7305.555556	150	48.7037										
Labor Hours:	Productivity											
7305.555556	0.08	584.444										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 41,569												
O&P												
Total O&P * Quantity												
$ 54,792												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 57,531												
Inflation between 2009 to 2014												
$ 63,860												

Appendix Table 35

Permits, Planning, Engineering				
*assume 5 miles				
Quoted $150 per foot				
will cover Permits, Engendering, Planning, and Contingency				
26400	Feet in 5 miles			
$ 3,960,000				

Nursery D:

Nursery D located in Maryland's Piedmont region has been in operation since 1980 and is comprised of 22 total acres with 16.5 acres used in actual production. The partial budget will be separated into two distinct options; the defenders, relating to recapture and recycling of water, and the challenger, relating drilling of additional wells in the area. The defender costs encapsulate filling the upper lot, labor related to earth moving, chlorine, digging out of the ponds, filtering, increased irrigation pipes and drains, dredging, the opportunity cost of the pond, digging of recapture pond, and increasing the size of the pond. The challenger option is comprised of the needed buffer capacity, digging of three extra wells, permits needed for these wells, purchase and installation for the well pumps, digging of buffer pond, and electricity for the wells. The Partial Budget Table D**Error! Reference source not found.** outlines the areas of costs and how they are related.

Partial Budget Table D

Partial Budget Table: Nursery D				
Defender			Challenger	
Recapture/Recycling of Water			Drilling of Wells	
Additional Costs			*Additional Returns*	
Fill in of upper plot (150 truck loads) [72]	$0		Reserve or Buffer Capacity[73]	$ 4,922
Labor & capital to move around soil[74]	$ 444			
Chlorine[75]	$70			
Digging of the ponds[76]	$1,466			
Filter[77]	$155			
Irrigation w/ pipes and drains[78]	$63			
Dredging [79]	$64			
Reduced Returns			*Reduced Cost*	
Opportunity Cost of the pond[80]	$ 600		Digging of 3 extra wells[81]	$ 829
Cost of Increasing Pond Size[82]	$ 1,516		State permits for the wells[83]	$ 71
			Installation and Purchase of Well Pumps[84]	$ 430
			Electricity for Pumps[85]	$ 389
			Digging of Buffer Pond[86]	$3,564
Total	$ 4,377		Total	$10,205
	Net Total	$(5,828)		

[72] Owner indicated the fill for the upper plot was free, and was 150 truck loads or 750 cubic yards
[73] The reserve proportion of the buffer pond was found by comparing the needed reserves and the capacity currently
[74] Labor and equipment cost were found from the LCB to move 750 cubic yards
[75] The chlorine was in tablet form and a comparable cost was found from a pool wholesaler
[76] Assume digging out of 4,560 square feet of area
[77] Cost from a comparable disc filter currently on the market
[78] Irrigation drains and grates that facilitate water to the recapture ponds
[79] Dredging occurs every 15 years and is based on the square footage of the ponds
[80] Costs relating to the forgone growing area the pond takes on
[81] Digging of 3, 4" to 6" 100 foot wells on the property
[82] Enlarging of the pond due small amount of water reserves which the nursery can draw upon
[83] Basic permits for the wells in the state of Maryland
[84] 3 Submersible pumps for a 5" well
[85] Electricity for the 3 submersible pumps for an entire year based upon the needed gallons and output of the wells
[86] Assume 11,091 square foot area to dig out

The farm did not need extensive work to reshape the drainage system. An entire portion of the property was erected to encompass a retaining wall holding 150 truckloads of dirt to fill and level the upper area. This area is mostly used for production of container plants, with the irrigation water being fed by two wells. These two wells produce a combined 45 gal/min of water from the water table below. The problem of acidic water is mitigated by the effluent running over limestone before reaching the surface for irrigation purposes. However, this is supplemented by the drainage system flowing into two recapture ponds. The ponds have an area of 450 and 120 square feet respectively. The owner believes that the ponds capture all of the runoff water exiting farm area with the smaller of the two ponds is supposed to feed the larger pond when the water level gets too low. The water is then pumped through a filter to clean it, as well as infused with chlorine to dismiss any present pathogens. The chlorine comes in tablets that are easy to handle and dispense.

Another precaution taken is that the recycled water is kept away from plants that may be susceptible to water borne diseases. The recycled water is used for drip irrigation purposes on heartier varieties of plants on the perimeter of the property. A problem with the recapture system can be the presence of algae in the ponds which can be caused by the runoff water absorbing fertilizer intended for plants. The owners use as slow release fertilizer to lessen the amount of nutrients that enter the ponds and could possibly clog the filter. When storms do occur, there is an abundance of water which will cause the ponds to be shut off, stopping sediment build up. Debris does get caught in the drainage pipes as well. The owner stated that if he were to redo the irrigation system he would make the pipes larger for the underground drains.

The recontouring of the property is a primary priority of Nursery D. As stated above there was major remodeling of the entire property for two reasons. The first was the need for a good irrigation surface, the other was to allow room for an office and sales portion on the property. The costs of recontouring and filling the large area are; 150 dump truck loads of dirt; which according to the owner was all free material, and the labor to remodel. However, while the materials for the recontouring may have been free the labor was not. The labor to move and form the soil in the upper lot cost $7,088, when amortized over 30 years' accounts for $444 annually. According to the owner, the building of the structurally sound, properly graded retaining wall with the addition of the storm water pipe; was also a large cost at $1,000 or $63 annually. Along with this earth moving; there was also the digging out of the recapture ponds themselves. Assuming an area of 4,560 square feet area the average cost would be $23,392 (Homewyse, 2015). This cost was amortized over thirty years to account for a bill of $1,466 annually.

The chlorine system used at operation D incorporates chlorine tablets, not the normal gas chlorination system. The nursery uses, on average, twenty pounds of chlorine tablets per year with the cost of twenty pounds of chlorine tablets going for $70 (Leslie's Swimming Pool Supplies, 2014). This total does not need to be amortized as it is a yearly cost. The filter, as specified above, has a useful life of four to five years that has a cost of $719 (Emperor Aquatics Inc., 2014). This filter uses small plastic discs to cleanse the water of any foreign debris. Thus the yearly cost of the filter is $155 when amortized over five year.

Additional wells would comprise the other water source for Nursery D. The operation already has very good well water so additional wells would probably glean similar reserves. As indicated on our visit there, three wells were found on-site producing 30gpm, 15gpm, and 10gpm (the 10gpm well supplied a nearby house). There would need to be three additional wells dug out to keep pace with the necessary irrigation. This is based off of the assumed need of 40,000 gallons of water per day in the growing season. It is also assumed that the water is split in half between the recycled and the current well water, thus meaning the three wells must supply that additional 20,000 gallons if recycling does not occur. If the two current wells, which provide for the nursery now, are at a combined 45gpm; then this is an apt goal for the three new wells. The reason three wells has been said is that if the average of the 30gpm, 15gpm, and 10gpm is about 18gpm. The hypothetical three wells at 18gpm would suffice to supply the nursery with the needed additional water.

The drilling of new wells would be $13,230 combined for the 3 wells, according to the RSMEANS book[87]. The total costs for all three would be amortized over 30 years and costs $829 annually. This line of logic also assumes that the wells will each produce 18gpm, and that there will be no other effect on the existing wells in the area. There will also need to be additional pumps purchased and maintained for these new wells. The additional motor and installation required for extraction of water from the wells will cost $3,623. Thus, the three additional units, amortized over a life of 10 years, come to $430 annually.

This operation is in Maryland, and there may be additional state costs associated with the permits for digging a well. These extra fees and licenses will also add to the costs of deviating from recycling. The permits needed would be; well construction permit, water appropriation and use permit, groundwater discharge permit, storm water

[87] (Spencer & Babbitt, 2008)

management, general permit for storm water, and well driller's license. Some of those permits are free of charge, but the overall cost of all the basic permits, from the methodology, is $1,130. The cost of the permits will be amortized over 30 years to come to a cost of $71 per year (The Maryland Department of the Environment, 2014).

The final expense for the reduced returns is the electricity needed to run the pumps in the three wells. The needed gpm for the nursery to get the same amount of forgone water that was not recapture and recycled is about 45 gpm; with this number each wells needs to produce about 18 gpm. The formula mentioned earlier was used to calculate the electricity needed for each pump then multiplied by the three pumps. The cost per hour of a single pump is $.0779 based upon the average cents per kWh in Maryland, $0.1087 (U.S. Energy Information Administration, 2014). The total amount of hours of pumping needed is 1665 hours, indicating that the total cost of electricity, on a yearly basis, for each pump would be $130, thus all three hypothetical pumps would be $389 (The Engineering Toolbox, 2014b).

As stated earlier the area being lost to pond space could be used in other endeavors for continued plant production. The reduced returns amounts to $600 based upon the acreage of the ponds and the relative cost per acreage of other nurseries of a similar revenue bracket. The totals square footage of the pond was 570 square feet. Combining this number with the average profit per square footage for their particular revenue bracket, of $0.12[88] per square foot, the total net of forgone profit is $600.

The buffer is based upon the needed reserves from the nursery in case of a power outage where there is no way to extract water. The way the amount for the buffer pond was found was using the number of gallons needed for seven days of watering then

[88] From Calculations regarding to the Cultice Survey results (2012)

dividing the total amount of gallons in the pond by that buffer to get a proportion. The value of the opportunity cost was that of the total initial pond, of $600, was then multiplied by that proportion, which was 8.208[89], to get the overall value of the buffer pond. The value of the buffer pond for nursery D was $4,922. To alleviate concerns about the size of the pond under the defender situation the cost to extend the pond for increased capacity was found. The increase in the ponds size is due to an internet calculator that uses the zip code and needed square footage to assess a range at which the pond could be reshaped (Daftlogic, 2014). The averages of the total estimates were taken from the estimated 4,679 square foot increase in the pond (it was assumed that the depth would remain constant at 8 ft). Average cost of digging a buffer pond of 11,091 square foot area would be $56,871 (Homewyse, 2015). Annualize costs would include $3,564 for the digging. This nursery is unusual in that the buffer capacity is larger than the actual lost space for the actual pond. The pond used by the nursery is too small to support the needed buffer and therefore cannot support the needed buffer area.

The total of all costs for the defender, or recapture/recycling program, is $4,377; while the challenger, relating to the digging of wells is $10,205. Thus the nursery has saved $5,828 by initialing implementing a recapturing and recycling irrigation system. However, it should be noted that a large portion of that total is influenced by the reserve/buffer pond.

Discussion for Nursery D:

Nursery D was an operation that was blessed with a very reliable source of water in the form of wells. The wells in question produced a large amount of water, at almost 30 gpm in respect to irrigation water. The wells provide 50% of the water and the rest

[89] See Appendix C for Proportion Table

was recycled. The nursery was started and then recontoured as a way to conserve water and expand production. As stated previously, land and water are the two main constraints when it comes to the expansion and profitability of the nursery.

When the reshaping occurred the nursery implemented and intricate recapture system into the ground around the retail and production areas. The plan utilized the location's slope to its advantage with regard to flushing the water into the two ponds. The ponds seem to be a limiting factor with regard to the future recapture of the operation. The ponds are small in relation to the daily uses of the nursery; even for the 50% that is used for recycling.   The capacity could be easily expanded in the future, which may be necessary as the nursery looks to make more profitable use of its land. The nursery does have about 6 acres of land that are wooded and provide extra storage space. This land could be used to both expand the ponds area and consequently the growing area of horticulture area.

The looming problem with nursery D seems to be the lack of reserves for a day or two. While this may be problematic at times, it is easily reconcilable. This problem may manifest itself when a drought year occurs as the wells may not be able to replenish the needed irrigation needs on its own due to the increasing size of the horticulture operation. If nursery D were to supplement its current wells with a backup well for possible drought uses there may be increased costs associated with such a strategy. There would be increased costs in relation to the digging of additional wells and electricity to operate those wells. Another possible cost could be the additional well could siphon gallons away from the wells currently in production on the underground water source. In light of these possible increases, it may be more beneficial to increases the capacity of the ponds as opposed to attempting to extract more water from the aquifer or underground spring.

The business as a whole seems to be recycling for the right reasons as they believe it is an ethical practice to conserve a finite good that is needed for the continued sustainability to their livelihoods. A possible tax relief or incentive may help this nursery in the long run to sustain and grow it recycling initiatives. These tax incentives could be a function of a water conservation policy.

Calculations for Nursery D:

Appendix Table 36

Filter		
Mechanical Disc Filter with a Back flush		
HD-3NA	Regular 3"/NPT Helix Disc Filter	
Price	718.8	
Life	15 years	

Appendix Table 37

Drainage System	
Concrete Pipe Grade #2	
$ 1,000.00	

Appendix Table 38

Amount of Chlorine gone through		
20 lbs		
Chlorine Tablets		
Nursery uses 20 lbs of chlorine tabs a year		
The cost of a 20 lb container is		
$ 69.99		

Appendix Table 39

Digging the Wells				
Digging of wells 4" to 6"				
Assuming 2 100 ft wells to be drilled				

Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-23	69.36	76.33	32	49.62	120	0.333	Linear Feet	0	11	23	33.7	42

Quantity Needed				
Conversation	300	0		3 100 foot wells
Productivity:				
Quantity		Duration		
Crew Days:	Daily Output			
300	120	2.5		
Labor Hours:	Productivity			
300	0.333	99.9		
Bare Costs:				
Materials:				
Bare Materials		*Assuming Linear use of material through work time		
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)		
$ 10,095				
O&P				
Total O&P * Quantity				
$ 12,600				
Contingency				
Increase Cost for Contingency (5%)				
Contingency Materials:				
Bare Costs*5% for waste and contingency				
$ 13,230				

Appendix Table 40

Installation of the Pumps			
Installation of a 1 H.P. submersible motor in the 3 new wells			

Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
Q-1	0	0	43.88	65.85	2.29	6.987	Pumps	615	305	0	920	1150

Quantity Needed			
Conversation	3	0	
Productivity:			
Quantity		Duration	
Crew Days:	Daily Output		
3	2.29	1.310043668	
Labor Hours:	Productivity		
3	6.987	20.961	
Bare Costs:			
Materials:			
Bare Materials		*Assuming Linear use of material through work time	
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)	
$ 2,760			
O&P			
Total O&P * Quantity			
$ 3,450			
Contingency			
Increase Cost for Contingency (5%)			
Contingency Materials:			
Bare Costs*5% for waste and contingency			
$ 3,623			

Appendix Table 41

Permit For Well					
		Cost	Life of Perm	number of wells	
		May not exceed		3	
3.14	Well Construction Permit	160			
3.15	Water Appropriation and Use Permit	No Fee			
3.05	Ground water discharge Permit				
3.21	Erosion/Sediment Control and Storm water Management	No Fee	No Expiration		
3.23	General Permit for Storm water Associated with Construction	less than 10 acres 100			
3.28	Well Drillers License	250-450 350			
Total for permits	1130				

Appendix Table 42

Dredging		
Assume a size ponds of 570 square feet		
Assume it costs $1.25 per square foot		
$ 1.25		The final amount for the reduced returns, is the electricity to run the pumps in the three wells. The needed gpm for the nursery to get the same amount of forgone water that was not recapture and recycled is about 78 gpm; with this number each wells needs to produce about 26 gpm. The formula indicated earlier was used to calculate the electricity needed for each pump then multiplied by the three pumps. The cost per house of a single pump is $10.43 based upon the average cents per KwH in Maryland, $0.1087. the total amount of hours of pumping needed is 1800 hours, indicating that the total cost of electricity, on a yearly basis, for the three pumps are $56,374.
Square footage		
570		
$ 713		

Appendix Table 43

Labor for Moving the soil in upper Area												
0020	Spread with 200 H.P. Dozer, no compaction, 2 mi.											
pg 278	Screened Loam											
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-15	76.71	84.39	34.59	57.77	600	0.047	Cubic Yards	20.5	1.6	3.58	5.19	9
								*assume material is 0 as owner said was free				
Quantity Needed												
Area	150	Truck loads	Cubic Yards per truckload									
Conversation	750	Cubic Yards	5									
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
750	600	1.25										
Labor Hours:	Productivity											
750	0.047	35.25										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 3,893												
O&P												
Total O&P * Quantity												
$ 6,750												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 7,088												

Appendix Table 44

Electricity of Pumps

The costs of pumping water can be calculated as

1 hp motor

Assume

$C = 0.746\ Q\ h\ c\ /\ (3960\ \mu_p\ \mu_m)$ (1)

where

C		*C = cost per hour*
	18	*Q = volume flow (gpm)*
	100	*h = head (ft)*
	0.1087	*c = cost rate per kWh*
	0.6	μ_p *= pump efficiency*
	0.788	μ_m*= motor efficiency*
	0.077959352	*Cost per hour*
	3	*Number of Pumps*
	0.233878057	*Total Per Hour*

Using Commercial 2014

MD is 10.87 cents per KwH

* Motor efficiency from http://www.engineeringtoolbox.com/electrical-motor-efficiency-d_655.html

Minimum nominal efficiency

Power (hp)	Minimum Nominal Efficiency[1)]
1-4	78.8
5-9	84
10-19	85.5
20 - 49	88.5
50 - 99	90.2
100 - 124	91.7
> 125	92.4

Where electricity is available, it is the most efficient power source. As shown in Table 1 on page 4, the efficiency of electric motors ranges from 80 percent for motors under 7.5 horsepower to over 90 percent for motors of 75 horsepower or larger. One disadvantage of electrical systems is that electric lines in many rural areas do not run near the water source, and three-phase power is often less available in these areas. Most electric companies require three-phase power

Electric Motor Size (horsepower)	Full Load Motor Efficiency (percent)	Typical Attainable Matched Size Pump Efficiency* (percent)	Pumping Plant Efficiency** (percent)
3-5	80 - 86	55 - 65	44 - 56
7.5 - 10	85 - 89	60 - 70	51 - 62
15 - 30	86 - 90	65 - 75	56 - 68
40 - 60	88 - 92	70 - 80	62 - 74
75 and larger	90 - 93	75 - 85	68 - 79

Hours of operation of well

If nursery get half of it 40,000 gallons from a combined 45gpm wells

Then gph of the wells is 2700

Then divide the 20,000 it need to cover by the 2700 to get

7.4 hours in growing season

We assume this is used on average for the entire growing seasons (7 month)

The other 5 months would be at a rate of 10% of the growing months

1554	Hours in the growing season
111	Hours in non-growing season
1665	Total hours yearly

Total Cost for Electric to pumps

$ 389 Cost for electricity to pumps

Nursery E:

Nursery E is a large operation north of Baltimore which began business 35-40 years ago. The land is well contained, and suitable for a recapture irrigation system. The entire property, which specializes in re-wholesaling, is 105 acres. The land was used in dairy production before being converted into a nursery. The partial budget will be separated into two distinct options; the defenders, whose function relates to recapture/recycling, and the challenger, which relates to piping in of municipal water. The defender costs encapsulate dredging, bubblers, herbicides, copper, a chlorine injection system, chlorine gas, digging of the recapture pond, and the opportunity cost of the pond. The challenger option is comprised of the opportunity cost of the buffer pond, digging of the buffer pond, a yearly rate for city water, installation of water meter connection, installation of the water pipes, yearly fees, and engineering, municipal fees, and permits related to the installation of the water pipes. The Partial Budget Table E outlines the areas of costs and how they are related.

Partial Budget Table E

Partial Budget Table: Nursery E			
Defender		Challenger	
Recapture/Recycling of Water		Municipal City Water	
Additional Costs		*Additional Returns*	
Dredging[90]	$1,187	Reserve or Buffer Capacity[91]	$ 976
Bubblers[92]	$ 747		
Herbicides[93]	$ 500		
Copper[94]	$ 2,000		
Chlorine System[95]	$ 848		
Chlorine Gas[96]	$ 2,240		
Digging Recapture Pond[97]	$113,057		
Reduced Returns		*Reduced Costs*	
Opportunity Cost of the Pond[98]	$ 40,726	Cost of Municipal water[99]	$ 23,236
		Water Meter 2" Install[100]	$ 376
		Yearly Water Fees[101]	$ 1,293
		Installation of Water pipes[102]	$ 8,848
		Engineering, Fees, Permits[103]	$ 248,140
		Digging of Buffer Pond[104]	$ 804

[90] Occurs every 15 years and is based off of the pond square footage
[91] The reserve proportion of the buffer pond was found by comparing the needed reserves and current capacity
[92] Used to aerate the pond
[93] Used to combat possible algal blooms in the recapture pond, is only used in growing season when blooms are prevalent
[94] Controls algal blooms and very similar to herbicides in the use and season in which employed
[95]Comprised of the chlorine injection and smart valve technology for this nursery
[96] Owner indicated 200 lbs are used annually
[97] Assume that 309,694 square feet area dug for pond
[98] Costs relating to the forgone growing area the pond takes on
[99] The rate for municipal water given the usages per year
[100] Cost of installing a 2’ water meter (no price was listed on the municipal site but assumptive estimations were made)
[101] Yearly Fees comprising of service, distribution, front foot and usage charges
[102] Cost of 5 miles of installation of water pipes to give the nursery access to irrigation water
[103] Other bureaucratic costs associated with the installation of a water pipe
[104] Assume that 2,199 square feet area dug for pond

Totals	$ 161,306			Total	$ 283,673
	Net Total	($122,367)			

The irrigation for the property is difficult as there are litanies of factors affecting the outcome. First, the utility pipeline for municipal water is miles away and the wells are inefficient because the wells are 600 feet down and produce only 10 gallons per minute. The well water constitutes 35% of the water used on the property while the other 65% comes from recapture/recycling techniques. Additionally, the water can be shipped in, but at a costly expense. In this case study, it is assumed the next best alternative is for the municipality to run a water line to the nursery at the expense of Nursery E. Tankers of water may be applicable based upon a short term situation, but for a long term strategy they are not feasible. A more feasible reality would be for the nursery to pay for a new pipeline from the county municipal utilities however this option is not ideal as there would be a variety of legal and municipal issues that would need to be overcome before the alternative could be done. This is merely the best alternative for the nursery to compare the recycling option, as it is assumed that the digging of the water pipeline would encounter no problems and would go over no areas that require additional cost.

There was no recontouring needed at Nursery E, as it was one of the few case studies from the visits that did not require land manipulation. The operation was originally a rather hilly daily farm with a pond already installed. This significantly cuts down the costs associated with recycling for operation E. However, the pond maintenance does require dredging every ten years, which comes at a cost of $10,000 per dredging[105]. Amortized over ten years, the cost annually would be $1,187.

To combat algal growth in ponds, nursery E used bubblers, herbicides and coppers. There are seven bubblers[106] installed at a price of $1,195 per unit; to a total of $8,365 and amortized for fifteen years at a cost of $747 annually. The yearly costs of herbicides and coppers are $500 and $2,000 respectively. Therefore the total amount spent per year to keep the pond healthy is $3,247.

The chlorine system consists of a chlorine injector which costs $2,000, and a smart-valve that costs $7,500. The total system costs are $9,500[107], amortized for 15 years, which amounts to $848 yearly. The other cost associated with the chlorine systems is the actual chlorine itself. Nursery E uses about 200 pounds per year[108], which will require them to have 2 canisters because each canister contains 150 lbs. each. The prices

[105] From grower visits
[106] (The Pond Report, 2014)
[107] (Regal Chlorinators, 2014)
[108] Based on visit and discussion with the owner

gathered from ASG were $1,120 per 150 lbs. cylinder (to rent), coming to a price of $2,240 for the 2 cylinders (Advanced Specialty Gases, 2014).

The pond of the nursery is rather large in comparison to other nurseries visited. This could be a function of the drought which they experienced at one point in the life of the business. The total area of the ponds is 309,694 square feet. Given the revenue bracket of the nursery the average profit per square foot is $0.13[109], indicating a large opportunity cost of the ponds in question. Thus the total forgone profit in terms of growing space is $40,726.The nursery has a small proportion of needed reserves in relation to the actual gallons from the current ponds. This is probably a function of the infeasibility with regard to other available water sources. This may be a function of the nursery having to truck in water during a drought in a prior growing season. As a result, this leads to the nursery increasing the reserves to alleviate possible future water issues. The nursery has such large ponds due to its need to mitigate possible shortages of water that may occur. Average cost of digging a 309,694 square foot area pond would be $1,804,248, and $113,057 annually (Homewyse, 2015).

The additional returns can be associated with the buffer pond. The buffer pond to be shown within this nursery is based on the proportion given with relation to the needed reserves against the current capacity. The proportion is very small, at .0059[110], based upon the small reserves needed and the large scale recapture capability of the nursery. Therefore, the buffer pond is the proportion multiplied by the opportunity cost of the pond, to elicit a value of $241. A value was also found with relation to the cost of filling the pond to the reserve capacity based upon the price of a cubic yard of soil and the

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[109] From Calculations regarding to the Cultice Survey results (2013)
[110] See Appendix C for Proportion Table

needed area to be filled relative to the known pond area presently. The total amount of the fill is $3,324,905 which when amortized over 30 years comes to a total of $208,344. This final cost with relation to the fill encompasses the earth needed as well as the labor to move and get the new growing area.

The installation of water pipes is a key for the formation of an extra alternative to get water access for the nursery. The nursery owner indicated that the area for a hookup to the municipal utility is about five miles away, meaning that five miles will be the assumed distance for water piping installation. The total amount for the entire installation would be $141,207 which is a very low estimate when talking to professionals in the industry (Spencer & Babbitt, 2008). This estimate included digging of the trench, laying the pipes, and backfilling the trench. However, given the parameters and assumptions initially put on the possible use of the water, this estimate should be used. It allows for the like estimate used to compare different operations within the study. The amortized total of the piping would be $8,848. According to an expert with regard to county permitting and planning a good rule of thumb would be $150 per foot of piping that was installed (Kennedy, 2015). The total cost entails all permits, fees and licenses that are part of the project. For the five mile installation the total cost would be $3,264,543 and amortized over 30 years would $204,561.

The operation will need a water meter of 2 inches at an assumed cost of $6,000, which amortized will be $376 over 30 years. There are yearly water fees including a usage charge, distribution charge and a front foot assessment; all amounting to $340 annually. Since nursery E demands 55,543 gpd (gallons per day), of that the nursery needs to pump in about 41,142 gallons that would normally be supplied by the recycled/

recaptured water. The necessary rate per day is based upon different units of consumption and the price per unit (or 748 gallons) goes down the higher tier of units bought. The water is bought per quarter, meaning that the nursery needs about 500,000 gallons per quarter, based upon the separation of growing and non-growing season breaks. The total amount of units needed per quarter is 670, or 501,160 gallons. The rate, using the tiered system, comes to $5,809 per quarter. Thus, the total annual amount is due at $23,237. There are also yearly water fees comprising of a usage charge, distribution charge, front foot assessment, and a service charge totaling $1,293 a year (Baltimore Public Works, 2015). The water would be stored in a buffer pond which would have to be dug out to accommodate the needed reserves. Average cost of digging a 3,119 square foot area pond would be $12,831, and $804 annually (Homewyse, 2015).

The total of all costs for the defender, or recapture/recycling program, is $161,306; while the challenger, relating to the municipal water costs is $283,673. Thus the nursery has saved $122,367 by implementing a recapturing and recycling irrigation system. However, it should be noted that a large portion of that total is influenced by the installation of water pipes.

Discussion for Nursery E:

Nursery E is located in a very profitable spot even though it is severely constrained by the physical area surrounding the nursery. The location is key as it is between two large metropolitan areas. This proximity to large populations shows the need for a location oriented business plan. The operation was bought from a dairy farm and converted to a horticulture operation with the awareness that these markets are in the immediate vicinity.

As much as the nursery is locationally appealing for market reasons it is equally unappealing for its resource constraints. The major problem is lack of well production in the area. The other nurseries in the state of Maryland rely on large quantities of well water to supplement their recycling efforts. The wells at nursery E go 600 feet down but have very limited returns.

Within the partial budget the alternative was discussed as pumping in of municipal water on a large scale to a secluded part of the mountains. It should be noted that one of the assumptions with regard to laying the water pipe was that there would be over flat relatively easily accessible land. Getting the municipal water line to this nursery would prove to be very difficult due to the topography of the area surround not only the municipal pipes but also where the municipal water line is situated.

Talking to a planner in the area of the nursery, he indicated that such a hypothetical pipeline would be entirely infeasible; not just from a cost perspective, but also from laws and ordinances perspective. The municipal water utility also showed concern for being able to meet the demand for the nursery with the water mains in that area of their jurisdiction.

This information at this point in the paper could seem to show that the partial budget was unwise to use for this type of analysis. However, this would also show the relative costs associated with a nursery of similar characteristics that may not have the same location and ordinance concerns this operation encounters.

This nursery shows the type of concern that recapture/recycling nurseries give to make sure that the water reserves available to them are as maximized as possible. Nursery E has no other choice but to maximize the amount of recaptured water they can take in. The business clearly values the access and amount of water very highly due to the overall size of their ponds relative to their needed buffer for seven days. The nursery may value the water reserves so highly due to the repercussions of a drought which passed over them on growing season when the ponds ran dry and truck loads of water needed to be shipped in at $60,000 a load. The owner was still very concerned about a possible reoccurrence of such an event even after the ponds were enlarged to increase the capacity.

Calculations for Nursery E:

Appendix Table 45

Cost of dredging	
10,000	
time	10 years

Appendix Table 46

Bubbler	
Quantity on nursery	
7	
Cost	
1,195	
Total costs	
8,365	

Appendix Table 47

Chlorine Systems		
System for chlorination		$2,000.00
Smart-Valve		$7,500.00
	Total	$9,500.00

Appendix Table 48

Chlorine Gas			
200 lbs			
Gas Price (per cylinder)			$575.00
Cylinder Price			$250.00
Cylinder Rental option (per month/ per cylinder			$12.50
Freight (375+20 hazmat fee)			$395.00
Total (per cylinder)			$1,220.00
Total (per cylinder) (12 mon. rental)			$1,120.00
Uses 200lbs a year			
Avg	200		
Tank contains	150		
	1.333333333		
So need 15 canisters	2		
will assume rental per cylinder			
Total cost for Chlorine	$2,240.00		

Appendix Table 49

Herbicides	
500	yearly

Appendix Table 50

Coppers	
2000	yearly
used once a month	

Appendix Table 51

Water Uses									
Have a well that produces 10g/m and a well is 35% of the irrigation									
Assume well runs for 8 hours a day									
Well output is 4,800	well output per	14400							
So 100/35 = 2.857		2.85714286							
and 4800*2.857		41142.8571							
55542.85714	gallons daily								
Therefore would only need a 1 inch water meter to be installed									
Will need to buy the water for the recycled									
41142.85714	gallons daily								
So the yearly gallons needed to be purchased were									
9,257,143									
There are quarterly rates									
So need	2,314,285.71	gallons per quarter							
1 unit = 748 gallons									
First 50 units	37,400.00	Gallons	50	Units					
Next 450 units	336,600.00	Gallons	450	Units					
Over 500 units	1,940,285.71	Gallons	2593.9649	Units					
							Price per gallon at each part		
First 50 units	50	Units	Rate	4.082	$ 204		$ 0.000109		
Next 450 units	450	Units	Rate	2.512	$ 1,130		$ 0.000007		
Over 500 units	2593.964859	Units	Rate	1.725	$ 4,475		$ 0.000001		
Total Water Cost					$ 5,809		$ 0.000039	Average Price per gallon	
Annual	Price per gallon								
$ 23,236.36	0.002510								

Appendix Table 52

Water Meter Installation			
Water Charges for a 4" meter			
Water Meter	6000		
Minimum Charges	480	Other Fees	1075
Service Charges	595		

Appendix Table 53

Water Pipes												
4560	4" Diameter	AWWA Class 150 SDR 18										
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost Bare	Crew Cost	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
Q-1A	0	0	43.88	65.85	686	0.015	Linear Feet	0.51	0.72	0	1.23	1.64
Quantity Needed												
Length	26300	Feet										
Conversation	26300	Linear Feet										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
26300	686	38.3381924										
Labor Hours:	Productivity											
26300	0.015	394.5										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 32,349												
O&P												
Total O&P * Quantity												
$ 43,132												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 45,289												
Inflation between 2009 to 2014												
$ 50,270												

Appendix Table 54

Trench for Municipal Pipes		pg 283										
5120	1-1/2 C.Y. Exca	Digging of Trench for Municipal Pipe at 4' to 6'										
Digging for a 2" pipe												
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost Bare	Crew Cost	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-12B	54.11	59.52	37.08	56.48	583	0.027	Cubic Yards	0	1.02	1.48	2.5	3.18
Quantity Needed												
Length	26300	Miles										
Width(Pipe Size ft)	1.5											
Depth	5	5' b/c in-between 4' and 6'										
Conversation	7305.555556	Cubic Yards										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
7305.555556	583	12.5309701										
Labor Hours:	Productivity											
7305.555556	0.027	197.25										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 18,264												
O&P												
Total O&P * Quantity												
$ 23,232												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 24,393												
Inflation between 2009 to 2014												
$ 27,077												

Appendix Table 55

Backfill of Trench												
	3100	Backfill Trench with F.E. loader, wheel mtd, with 2-1/4 C.Y. bucket										
Filling in 5' deep trench with 12" municipal water pipe laid in for 5 miles												
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost Bare	Crew Cost	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-10T	32.98	36.28	38.1	57.77	150	0.08	Loose Cubic Y	0	3.05	2.64	5.69	7.5

Quantity Needed		
Length	26300	Feet
Width(Pipe Size ft)	1.5	
Depth	5	5' b/c in-between 4' and 6'
Conversation	7305.555556	Cubic Yards
Productivity:		
Quantity		Duration
Crew Days:	Daily Output	
7305.555556	150	48.7037037
Labor Hours:	Productivity	
7305.555556	0.08	584.444444
Bare Costs:		
Materials:		
Bare Materials		*Assuming Linear use of material through work time
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)
$ 41,569		
O&P		
Total O&P * Quantity		
$ 54,792		
Contingency		
Increase Cost for Contingency (5%)		
Contingency Materials:		
Bare Costs*5% for waste and contingency		
$ 57,531		
Inflation between 2009 to 2014		
$ 63,860		

Appendix Table 56

Everything included			
*assume 5 miles			
Quoted $150 per foot			
will cover Permits, Engendering, Planning, and Contingency			
26400	Feet in 5 miles		
$ 3,960,000			

Appendix Table 57

Water Fees for County	
Usage Charge	480
Distribution Charge	98.11
Front Foot Assessm(	120
Service Charges	595
Total	1293.11

Nursery F:

Nursery F is located in the coastal plains of Maryland. The entire complex is 50 to 60 acres, with 6 acres devoted to a state-of-the-art greenhouse system. A portion of the property is inhabited by a different business that sells to other nursery wholesale supplies. Recycling of irrigation water was a main concern when a plan for designing and shaping the property was implemented. All of the acres, from both businesses, funnel directly into a large pond with a 2.5 million gallon capacity at the bottom of the property. The pond is directly fed through runoff, either from irrigation or rain water. If, however, the pond's water level gets too low, the pond can be supplemented from an onsite well. The well is operated by a 10 Hp motor which draws water from a well that is less than 100 feet deep. If the recycling of water was not an option, the only other feasible alternative would be to drill more wells. The closest municipal lines for water are miles away. Therefore, the only option for Nursery E from the outset was either to design a recycling operation or to drill more wells into the water table. The nursery also has to deal with effluent spill-off. The property abuts a stream that can handle any excess runoff from severe storms.

The partial budget will be separated into two distinct options; the defenders, relating to recapture/recycling, and the challenger, relating to drilling of additional wells. The defender costs encapsulate copper, bubblers, chlorine injection system, chlorine gas, bromine tablets, dredging, smart valve, digging of recapture pond, and the opportunity cost of the pond. The challenger option is comprised of the opportunity cost of the buffer pond, digging of the buffer pond, drilling of additional wells, installation of pumps, permits related to the additional wells, and electricity for the wells. The Partial Budget Table F outlines the areas of costs and how they are related.

Partial Budget Table F

Partial Budget Table: Nursery F				
Defender			Challenger	
Recapture/Recycling of Water			Digging of Wells	
Additional Costs			*Additional Returns*	
Copper [111]	$ 587		Reserve or Buffer Capacity[112]	$ 4,816
Bubbler[113]	$ 107			
Chlorine[114]	$ 5,600			
Bromine tablets[115]	$ 1,000			
Recontouring [116]	$ 108,473			
Dredging [117]	$ 9,588			
Chlorine Systems[118]	$ 179			
Smart Valve[119]	$ 670			
Digging of Recapture[120]	$29,516			
Reduced Returns			*Reduced Costs*	
Opportunity Cost of Pond[121]	$ 39,293		Drilling of additional wells[122]	$ 829
			Installation of Pumps[123]	$ 1,767
			Permits for Additional Wells and Water[124]	$ 71
			Electrical for additional wells[125]	$ 564
			Digging of Buffer Pond[126]	$1,073
Total	$ 177,870		Total	$ 9,120
	Net Total	$ 168,750		

[111] Used to control algal blooms in the lake assuming a 2 weeks treatment time for 12 weeks of summer
[112] The reserve proportion of the buffer pond was found by comparing the needed reserves and the capacity currently
[113] Aerates the pond to keep the water healthy
[114] Chlorine gas usage for the nursery is around 650 to 700 lbs. per year
[115] Tablets used to combat diseases
[116] Assumed 30 acres at 2.5 yards were recontoured (based upon the hilly nature of the surrounding land)
[117] Assumed to occur every 15 years and is based off of the square footage of the pond
[118] Assuming just the chlorine injection system
[119] Smart valve used to regulate the amount of chlorine used for each growing area
[120] Assume 85,883 square foot area dug out
[121] Costs relating to the forgone growing area the pond takes on
[122] Digging of 3, 4" to 6" 100 foot wells on the property
[123] 3 Submersible pumps for a 5" well
[124] Basic permits for the wells in the state of Maryland
[125] Electricity for the 3 submersible pumps for an entire year based upon the needed gallons and output of the wells
[126] Assume 3,119 square foot area dug out

Large problems with the latter of the two choices were the Maryland permits for wells. The increased costs of extracting additional water may have been a deterrent to erecting such a large scale extraction operation. Right now the operation has a 25 million gallon permit to extract water. Annually they are very close to this number between the two businesses on the property. The problem would be that Nursery F goes through between 80-90,000 gallons of water daily; and 100,000 gallons on especially hot days. This would require a large outlay of capital for wells and permits to meet the demand. This may seem as a small amount of water used over such a large area; however the operator invests extensively in drip irrigation techniques. The nursery uses both the spaghetti system and irrigation tape. Nursery F believes these techniques save them large amounts of money every year on water costs. These water saving techniques occur when water percolates directly to the root and is not stuck on the leaves, where it can evaporate. Also the drip irrigation can have other benefits; most notably decreasing algal blooms in the pond. Because of the drip irrigation can be effective at reducing runoff, the nursery does not use slow release fertilizers. The managers want to control what goes on the plants in terms of fertilizers and nutrients. Algal blooms are really only an issue between June, July, and August, when the hot weather allows the algal blooms to take hold of the pond.

The greenhouse is another interesting aspect to this particular operation. Covering about six acres of space, it is a completely impermeable surface that captures all of the runoff and drains it into the pond. A majority of the water is retained within the greenhouse and funneled into two 30,000 gallon tanks. The large tanks are cycled out every month to stop the buildup of fertilizers in the water source.

The majority of the money is made in the spring and summer months between May and June. The entire rest of the year is an attempt to mitigate as much of the losses as possible through other sales. The Nursery sells Poinsettias in the winter to ease the losses and keep cash flowing to employees over the winter.

To combat algal growth in the ponds nursery F uses coppers and bubblers on the pond. The cost of the copper is $40 per gallon and $98 per treatment (Aquatic Biologists, 2014b). With a copper treatment every 2 weeks, the total cost for a summer would be $587 a year. The bubbler costs $1,300 over 15 years and that total is amortized to $116 yearly(The Pond Report, 2014).

The chlorine mitigates some of the possible losses through the growing season. The chlorine also reacts with the iron in the water to make it soluble. This effectively accomplishes two goals at once by staving off the pathogen problems, and also preventing iron from getting to the plants.

The nursery uses gas chlorination with chlorine system as well as a smart valve. The costs are $2,000 and $7,500 respectfully (Regal Chlorinators, 2014). These totals were amortized over a period of 15 years and come to a total of $179 for the chlorine system and $670 for the smart valve per year. The annual use of chlorine by nursery F is 650 lbs. on average. The canisters come in 150lbs. container which cost $1,120 for the rental of a canister (Advanced Specialty Gases, 2014). Given the amount of chlorine needed, a total of 5 canisters would be necessary. The total cost in chlorine per year being $5,600.

Bromine tablets are a strategy that is unique to this nursery as opposed to the other nurseries visited. The tablets help to cleanse the water of pathogens and other diseases. Bromine tablets cost the nursery $1,000 a year[127].

To allow for the maximum recapture from the property the land is assumed to be recontoured. However, the surrounding land is very conducive to recapture, so it will be assumed that only half of the land will be involved in the recontouring. Thus 30 acres of land will need to be manipulated at an assumed depth of 2 yards, bringing the total cubic yards to be recontoured at 290,400. The formulas for the removal and grading of the land from the LCB[128] total to $1,094,663 and $362,855 respectively. If the total of $1,457,518 were amortized over 30 years the annual cost would be $91,330.

The dredging of the pond comes at a cost of $110,000 and would occur every 15 years. The cost of dredging comes from the rule of thumb used for $1.25 per square foot, and from an 88,000 square foot pond comes to $110,000 (Donahoe, 2015). Therefore, the annual cost of the dredging would amount to $9,824.

The cost of the space for the pond had to be estimated a variety of ways. The owner did not tell us the exact revenue per year of the operation so an estimate was needed to properly value the area of the ponds. To get the estimate the original survey from Cultice (2013) was used to help find the revenue based on similar characteristics. Due to the fact that water is such a determining factor, the source and recapture of water were key components final number. The nurseries which exhibited similar characteristics of well water and water recapture averaged revenue between $500,001 - $750,000. The total square footage of the pond was 85,883 square feet. Combining this number with the

[127] Given by grower
[128] (Spencer & Babbitt, 2008)

average profit per square footage, of $0.46[129] per square foot, the total of forgone profit is $39,293. The digging of a 85,883 square area pond would be $471,043, and $29,516 annual over thirty years (Homewyse, 2015).

The buffer is based upon the needed reserves from the nursery in case of a power outage where there is no way to extract water. The way amount for the buffer pond was found was using that number of gallons needed for seven days of watering then dividing the total amount of gallons in the pond by that buffer to get a proportion. The value of the opportunity cost was that of the total initial pond was then multiplied by that proportion to get the overall value of the buffer pond. Pond proportion for the nursery was .122[130] which when multiplied by the value of the buffer pond of $39,293 produces a value of the buffer pond for nursery F was $4,816. The digging of the buffer pond would cost $17,125 for a 3,119 square feet of area, and an annual amount of $1,073 (Homewyse, 2015).

The alternative water source of this nursery would be additional wells to be drilled. The drilling of three wells at a 150 foot depth would be $13,230[131]. The purchase and installation of 5 HP submersible pumps account for $14,884 combined total for all three wells. Both of these numbers were amortized over 30 years and 10 years respectively. Thus the annual cost of digging the wells was $829, while the well pumps and installation cost $1,767 yearly. There are permits[132] and costs associated with the digging of the wells, these costs associated come to a total of $1,130 and amortized over 30 years makes for a cost of $71 per year.

[129] From Calculations regarding to the Cultice Survey results (2013)
[130] See Appendix C for Proportion Table
[131] (Spencer & Babbitt, 2008)
[132] (The Maryland Department of the Environment, 2014)

The final reduced returns are the electricity to run the pumps in the three wells. The needed gpm for the nursery to get the same amount of forgone water that was not recaptured and recycled is about 78 gpm; with this number each well needs to produce about 26 gpm. The formula indicated earlier was used to calculate the electricity needed for each pump then multiplied by the three pumps (The Engineering Toolbox, 2014a). The cost per house of a single pump is $10.43 based upon the average cents per KwH in Maryland, $0.1087 (U.S. Energy Information Administration, 2014). The total amount of hours of pumping needed is 1800 hours, indicating that the total cost of electricity, on a yearly basis, for all three pumps are $564.

The total of all costs for the defender, or recapture/recycling program, is $165,502; while the challenger, relating to the digging of additional wells is $59,043. Thus the nursery is spending an extra $106,459 by initialing and implementing a recapturing and recycling irrigation system. The meaning of this number will be elaborated on more in the discussion section of the paper.

Discussion for Nursery F:

Nursery F contained a fully operation greenhouse where water is conserved in two 30,000 gallon containers. This was the only nursery seen with such a set up for recycling and conserving water on a scale that could encompass a greenhouse. The water in the two containers was phased out every month to ensure there was no build up with relation to fertilizers or nutrients. This strategy was a key component, especially with relation to the amount of water used in the boom watering of the plants in the area. While this type of usage for water conservation is impressive it requires are large capital outlay upfront to mitigate the costs.

Such a strategy indicates that the company believes that the costs of water will increase in the future. The investment into the large scale cost items indicates a belief that the discount factor, with regard to waster will be greater in the future than the amortization of these technologies.

As seen within the initial case studies, the cost or recontouring is a large outlay that has a major impact of the budget of the nursery. In the case studies it has seemed that the nursery will only recontour if there is no other option for water present to them. They must be able to assess the current condition of the ground around the nursery to determine the best course of action as it pertains to the survivability of the operation. Overall it seems the nursery is foreseeing that increasing water rates will be the biggest detriment to their future probability rather than access to more land or water.

This is shown again with the way in which the well onsite at the nursery produces plentiful water. The nursery also may be concerned about the rate of extraction with regard to water into the future; such as an amount per gallon removed from the water table.   It seems that the thought of future regulations or fees was more than enough to convince the owners and planners of the nursery that recapture/recycling was a superior option to conventional well irrigation.

Calculations for Nursery F:

Appendix Table 58

Coppers	
Use for 1.5 acres foot of water per gallo	
Acres are 3.67 size of lake	
	2.446666667
Use every 1 to 2 weeks	
with 12 weeks of summer	
and needing 2 gallons per spreading	
Costs per gallon	
	$40.00
Per treatment	$97.87
Once per week costs	
	$1,174.40
Every 2 weeks	
	$587.20
*Assuming used every 2 weeks	

Appendix Table 59

Water		
Use about 90,000 on regular day (on average)		
so		
90000	daily	
2700000	Main monthly	

Appendix Table 60

Chlorine Gas			
600-700 yearly			
Assume	650		
Gas Price (per cylinder)			$575.00
Cylinder Price			$250.00
Cylinder Rental option (per month/ per cylinder			$12.50
Freight (375+20 hazmat fee)			$395.00
Total (per cylinder)			$1,220.00
Total (per cylinder) (12 mon. rental)			$1,120.00
Assume used 650			
Avg	650		
Tank contains	150		
	4.333333333		
So need 15 canisters	5		
will assume rental per cylinder			
Total cost for Chlorine	$5,600.00		

Appendix Table 61

Chlorine Systems		
System for chlorination		$2,000.00
Smart-Valve		$7,500.00
	Total	$9,500.00

Appendix Table 62

Bubbler	
Quantity on nursery	
1	
Cost	
1,195	
Total costs	
1,195	

Appendix Table 63

Dredging		
Rule of thumb cost per square foot of pond		
$ 1.25		
Square footage of the pond		
85882.57		
Total to dredge		
$ 107,353		
Assume lasts 15 years for a dredging		

Appendix Table 64

Regrading												
Assuming that 5 acres were converted to cubic feet the total cubic foot												
	30	Acres										
pth of 3 feet then the total footage would be												
1	1306800		2	yard depth								
	145200	square yards										
		290400	cubic yards									
Loam or Topsoil rer	for 500' Haul											
1440												
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipme nt	Total	Total O&P
B-10B	90.17	99.18	38.1	57.77	225	0.053	Cubic Ya	0	2.03	4.81	6.84	8.4
Quantity Needed												
Conversation	290,400.0000	Yards		*Assuming all don't in house								
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
290400	225	1290.666667										
Labor Hours:	Productivity											
290400	0.053	15391.2										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 589,512												
O&P												
Total O&P * Quantity												
$ 1,042,536												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 1,094,663												

Appendix Table 65

Regrading												
Grading of the slope at the property												
pg 281												
Assuming that the area is 15000 Square yards												
Fine Grade for small irregular areas												
1050												
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-32C	90.17	99.18	38.1	57.77	2000	0.024	Square Y	0	0.88	0.93	1.81	2.38
Quantity Needed												
Conversation	145,200.0000	Yards										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
145200	2000	72.6										
Labor Hours:	Productivity											
145200	0.024	3484.8										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 262,812												
O&P												
Total O&P * Quantity												
$ 345,576												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 362,855												

Appendix Table 66

Digging the Wells												
Digging of wells 4" to 6"												
Assuming 3 100 ft wells to be drilled												
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-23	69.36	76.33	32	49.62	120	0.333	Linear Fe	0	10.65	23	33.65	42
Quantity Needed												
Conversation	300	0		3 100' wells								
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
300	120	2.5										
Labor Hours:	Productivity											
300	0.333	99.9										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 10,095												
O&P												
Total O&P * Quantity												
$ 12,600												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 13,230												

Appendix Table 67

Installation of Pumps												
Installation of a 5 H.P. submersible motor in the 2 new wells												
Assuming 2 100 ft wells to be drilled												
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
Q-22	24.02	26.43	40.48	61.16	1.14	14.035	Pumps	2775	615	675	4065	4725
Quantity Needed												
Conversation	3	0	2 100 foot wells									
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
3	1.14	2.631578947										
Labor Hours:	Productivity											
3	14.035	42.105										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 12,195												
O&P												
Total O&P * Quantity												
$ 14,175												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 14,884												

Appendix Table 68

Permit For Well				
			Cost	Life of Permit
3.14	Well Construction Permit		May not exceed 480	
3.15	Water Appropriation and Use Permit			
3.05	Ground water discharge Permit			
3.21	Erosion/Sediment Control and Storm water Management		No Fee	No Expiration
3.23	General Permit for Storm water Associated with Construction		less than 10 acres 300	
3.28	Well Drillers License		250-450 350	
Total for permits	1130			

Appendix Table 69

Electricity of Pumps

The costs of pumping water can be calculated as

1 hp motor

Assume		$C = 0.746\ Q\ h\ c / (3960\ \mu_p\ \mu_m)$ (1)
		where
C		*C = cost per hour*
	25.69444444	*Q = volume flow (gpm)*
	100	*h = head (ft)*
	0.1087	*c = cost rate per kWh*
	0.6	μ_p *= pump efficiency*
	0.84	μ_m*= motor efficiency*
	0.104395525	*Cost per hour*
	3	*Number of Pumps*
	0.313186574	*Total Per Hour*

Using Commercial 2014

MD is 10.87 cents per kWz

* Motor efficiency from http://www.engineeringtoolbox.com/electrical-motor-efficiency-d_655.html

Minimum nominal efficiency

Power (hp)	Minimum Nominal Efficiency[1)]
1-4	78.8
5-9	84
10-19	85.5
20 - 49	88.5
50 - 99	90.2
100 - 124	91.7
> 125	92.4

Where electricity is available, it is the most efficient power source. As shown in Table 1 on page 4, the efficiency of electric motors ranges from 80 percent for motors under 7.5 horsepower to over 90 percent for motors of 75 horsepower or larger. One disadvantage of electrical systems is that electric lines in many rural areas do not run near the water source, and three-phase power is often less available in these areas. Most electric companies require three-phase power for motors that deliver more than

Electric Motor Size (horsepower)	Full Load Motor Efficiency (percent)	Typical Attainable Matched Size Pump Efficiency* (percent)	Pumping Plant Efficiency** (percent)
3-5	80 - 86	55 - 65	44 - 56
7.5 - 10	85 - 89	60 - 70	51 - 62
15 - 30	86 - 90	65 - 75	56 - 68
40 - 60	88 - 92	70 - 80	62 - 74
75 and larger	90 - 93	75 - 85	68 - 79

https://www.bae.ncsu.edu/programs/extension/evans/ag452-6.html

GPM for wells		* assume 8 hr of well production
Average GPD	85000	
well now is 100 gpm so gpd (8 hr)	48000	
So need wells to co	37000	
GPM needed	77.08333333	
Divided up from 3 w	25.69444444	Needed per well

Hours of operation of well

If nursery get half of it 40,000 gallons from a combined 45gpm wells

Then gph of the wells is 2700

Then divide the 20,000 it need to cover by the 2700 to get

8 hours in growing season

We assume this is used on average for the entire growing seasons (7 month)

The other 5 months would be at a rate of 10% of the growing months

1680	Hours in the growing season
120	Hours in non-growing season
1800	Total hours yearly

Total Cost for Electric to pumps

$ 564 Cost for electricity to pumps

Nursery G:

Nursery G is a business located in the ridge and valley region of Pennsylvania that was started in 1939 with 22 acres of land. The nursery has been expanding since its creation through the purchase of neighboring properties. Slowly, the nursery has expanded to encompass a large swath of property in the surrounding area. The partial budget will be separated into two distinct options; the defenders, relating to recapture/recycling, and the challenger, relating to drilling of additional wells. The defender costs encapsulate algaecide, coloring, dredging, and the opportunity cost of the pond. The challenger option is comprised of the opportunity cost of the buffer pond, cost to fill the excess area of the pond, drilling of additional wells, installation of submersible pumps, permits related to the additional wells, piping in of water from one mile away, wire for the wells, outlets for the wells, and electricity for the wells. The Partial Budget Table G outlines the areas of costs and how they are related.

Partial Budget Table G

Partial Budget Table: Nursery G			
Defender		Challenger	
Recapture/Recycling of Water		Digging of Wells	
Additional Cost		*Additional Returns*	
Algaecide[133]	$ 1,527	Reserve or Buffer Capacity[134]	$ 984
Coloring [135]	$ 1,457		
Dredging[136]	$ 9,476		
Digging of Recapture Pond[137]	$31,622		
Reduced Returns		*Reduced Costs*	
Opportunity cost of pond[138]	$11,162	Digging of additional wells[139]	$ 613
		Installation of Submersibles[140]	$ 1,351
		Piping from 1 mile away[141]	$ 1,394
		Electricity for Pumps in wells[142]	$ 145
		Permits for Piping[143]	$ 49,628
		Wire for Wells[144]	$ 241
		Installation of Outlets[145]	$ 646
		Digging of Buffer Pond[146]	$828
Total	$ 55,243	Total	$55,831
Net Total	($588)		

The farm is a large field production, with a small area dedicated to a container nursery. There is a recapture pond at the nursery in close proximity to the container

[133] Used to control algae in the pond, told the nursery uses about 102 gallons a year
[134] The reserve proportion of the buffer pond was found by comparing the needed reserves and the capacity currently
[135] Used to stymie algal growths in water, told the nursery uses about 47 gallons a year
[136] Assumed dredging every 15 years on the entire pond (is based upon square footage of the pond)
[137] Assume 84,877 square feet of area dug out
[138] Costs relating to the forgone growing area the pond takes on
[139] Digging of 2, 4” to 6” 100 foot wells on the property
[140] 2 Submersible pumps for a 5” well
[141] Installation of irrigation pipes to carry the water from the wells to the nursery over a distance of 1 mile; involves trenching, laying the pipes, and the backfilling
[142] Electricity for the 2 submersible pumps for an entire year based upon the needed gallons and output of the wells
[143] Costs associated with running the irrigation pipes between, engineering, permits, and fees
[144] Wire to transfer electricity from the nursery to the well site
[145] Installation of 3 waterproof outlets to power the well pumps
[146] Assume 2,218 square feet of area dug out

area.   This pond is interesting because it is fed by an underground spring, which supplements the recapture. The irrigation for the nursery is well-based and highly productive. They nursery has a 100 gal/min well with an 8 inch casing; this is good for being in such mountainous area. The container nursery alone uses 10,000 gallons a day.

The nursery uses the recapture pond for irrigation of the container plot because they feel it is more cost effective than continuing well water production of the container area, a large problem when using the lake is the algal blooms. The owner uses algaecide to combat the problem as well as lake coloring. The algae can get into the pumps and cause break downs which is why an algal bloom must be dealt with quickly. Nursery G has been attempting to lessen, possibly eliminate, its fertilizer use in the future. A move like this would drastically cut down the presence of algae in the irrigation pond.

Other problems include the buildup of sediment in the pond. The pond must be dredged periodically; however, it is challenging to get a professional dredging operation. A botched dredging operation could render the entire pond useless in the future. The final problem with the pond is the presence of *Pythium* and *Phytophthora* in the surrounding soils. When a large storm occurs, the runoff to the pond could be full of the pathogens. The use of Buckwheat is crucial to the containment of these pathogens, as the Buckwheat act as a cover crop for the nursery. Nursery G found the regulations regarding water almost non-existent. There was no dictation of how much effluent could spill into specific rivers, streams, or other water ways. Since the land was already contoured to suit recapture and the pond was previously present the additional costs associated with recycling of water would deal mostly with algal blooms and pond maintenance.

The costs include algaecide, coloring, and dredging of the pond. The algaecide and coloring are used only in the summer months when it is warm enough for the algal bloom to become a real problem. The overall annual costs of the algaecide and coloring is $1,527 and $1,457 respectively. The algaecide total would be 102 gallon at $14.97 per gallon (Home Depot, 2015a). The coloring would consist of 47 gallons at $31 apiece (Aquatic Biologists, 2015). The dredging amount was gathered from a dredging company which indicated that a good "rule of thumb" when dredging a pond would be for $1.25 for every foot (Donahoe, 2015). The total pond is approximately 84,877 square feet according to Daft Logic area calculator (Daftlogic, 2014). Dredging takes place every fifteen years and is done by a professional at a price of $106,096. This was amortized over the amount of times between dredging to come to an annual total of $9,476. The digging of the actual pond of the capacity at the nursery would be $504,64 for a 84,877 square foot area, and be a yearly amount of $31,622 (Homewyse, 2015).

The reduced returns are just the opportunity cost of the space occupied by the pond. This as stated previously is the area of the pond and the price the owner would pay for additional land in the area. Thus, the opportunity cost of the pond is $11,162 indicated by the price of $0.13[147] per sq ft and the area of the pond being 84,877.

The buffer is based upon the needed reserves from the nursery in case of a power outage where there is no way to extract water. The way the amount for the buffer pond was found was using that number of gallons needed for seven days of watering then dividing the total amount of gallons in the pond by that buffer to get a proportion. The value of the opportunity cost was that of the total initial pond was then multiplied by that proportion to get the overall value of the buffer pond. This is due to the large capacity,

[147] From Calculations regarding to the Cultice Survey results (2013)

which the nursery H pond has at its disposal. Pond proportion for the nursery was .019[148] which when multiplied by the value of the buffer pond of $984 for nursery G. The digging out of the buffer pond is an important to keep a reserve of water on the premises. Cost of digging a buffer pond would be $13,207 and annualize to $828 (Homewyse, 2015).

Lastly, the reduced costs are the drilling of wells to gain the needed water to replace the recapture/recycle system. According to the owners, there is not enough water in the immediate area for there to be the substantial well production needed to support the nursery without recycling. To alleviate that impediment in this study we are assuming that the pumps will be situated a mile away, in an area with easy access to the water table, and piping will bring the water to the nursery. There will be two assumed wells of 5" at depths of 100 feet. The cost of the digging will be $9,790 and amortized for thirty years to an annual cost of $613. The wells will need submersible pumps capable of forcing the water to the surface. The pumps and installation costs are $11,014 every ten years amounting to $1,351 per year. The next obstacle involves the piping associated with the nursery. As stated previously, the nursery will place the pumps in an area one mile away; these pipes must be laid to get the water from the wells to the nursery. The cost associated with digging the trench, laying the pipes, and backfilling the trench will be $22,179[149]. Through amortization over thirty years the total cost would be $1,390 yearly. The final reduced cost is linked to the electricity to run the motors for the pumps. The total calculated cost per hour of the pumps at the need gallons per hour $0.0804 (U.S.

[148] See Appendix C for Proportion Table

[149] (Spencer & Babbitt, 2008)

Energy Information Administration, 2014). Extrapolating that number over the entire year meant the total annual cost to run the pumps was $145.

Due to the lack of water immediately around the nursery water would need to be pumped in from one mile away. Thus, there would be need for irrigation piping for that mile distance. The assumed fees associated with the digging of the trenches with regard to land and water permits. The permitting, licensing, and fees involved account for $7,920 based on $1.25 per foot as indicated by an industry professional with a rule of thumb(Donahoe, 2015). That total was amortized over 30 years for $496 per year. To run the pumps at the remote location wiring, assumed to be embedded in with the piping to reach new well area. The total cost of the wire for the distance is $3,844 (Home Depot, 2015b). Along with the wiring there would need to be installation of waterproof outlets that could power the wells. The cost of the outlets would be $10,315[150]. The total of the wiring and outlets for the wells would be $14,159; this would amount to $887 per year.

The total cost for the defender, or recapture/ recycling option is $55,243, while the total for the challenger is $55,831 for increased use of well water. Thus, the net savings in relation to the using recapture/recycling irrigation techniques would be $588. It should be noted that a large portion of the challenger budget is comprised of the cost to permits of piping in water from the wells.

Discussion for Nursery G:

This nursery recycles out of convenience for the initial setup of the business. The general slope and angle of the land allows for a large opportunity for recapture from their farm. A large pond was initially built in at the base of the hill so that all the water could

[150] (Spencer & Babbitt, 2008)

runoff from the abutting hill. The pond is also fed by an underground spring located below the property.

The nursery relies on a majority of rainwater from the surrounding area to water most of its plants. The pond is therefore used mainly for the small container area that makes up a small percentage of the land used in production by the nursery. Due to the limited area of the container nursery production there does not seem to be a real risk with regard to the pathogens contaminating a large swath of plants. That being said, the business uses the Buckwheat as their only preventative measure for pathogen leaching into the water.

It seems for this nursery the activity of recycling cut down on the overhead costs of a new facet of their business. The nursery never started out as a container pot in pot nursery but rather saw the opportunity in the market and started a sector for their operation to get another revenue stream. Due to the addition of this opportunity the nursery used the existing pond to cut the available overhead by using the pond already present on the property for irrigation purposes.

This nursery used the topographic capabilities of their surrounding area to their advantage. It should be noted that the nursery did not start out as strictly as a container nursery, but chose that path due to its advantage in its access and availability of water. If waster rates increase into the future such advantages could prove the difference between the bankruptcy and survivability of the pot and pot business.

<u>Calculations for Nursery G:</u>

Appendix Table 70

Algcide		
102	gallons per year average	
$ 14.97	cost per Algcide gallon	
$ 1,526.94		

Appendix Table 71

Coloring		
47	gallons per year average	
$ 31.00	cost per Algcide gallon	
$ 1,457.00		

Appendix Table 72

Dredging		
Rule of thumb cost per square foot of pond		
$ 1.25		
Square footage of the pond		
84877.11		
$ 106,096		
Assume lasts 15 years for a dredging		

Appendix Table 73

Water Uses							
Uses about 10,164 gallons daily.			48000				
According to the 7 months or use an 5 month of 10% use the total used for the entire year is							
304,920.00							
Have a wells at 100/gal per minute with and 8inch casing							
well capacity is not there so uses the pond							
Will assume that 2 additional 4 inch wells will be							

Appendix Table 74

Water Pipes												
4560	2" Diameter	AWWA Class 150 SDR 18										
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
Q-1A	0	0	43.88	65.85	686	0.015	Linear Feet	0.51	0.72	0	1.23	1.64
Quantity Needed												
Length	5280	Miles										
Conversation	5280	Cubic Yards										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
5280	686	7.696793003										
Labor Hours:	Productivity											
5280	0.015	79.2										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 6,494												
O&P												
Total O&P * Quantity												
$ 8,659												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 9,092												
Inflation between 2009 to 2014												
$ 10,092												

Appendix Table 75

Trench for Municipal Pipes												
5120	1-1/2 C.Y. E:	Digging of Trench for Municipal Pipe at 4' to 6'										
Digging for a 2" pipe												
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-12B	54.11	59.52	37.08	56.48	583	0.027	Cubic Yards	0	1.02	1.48	2.5	3.18
Quantity Needed												
Length	5260	Miles										
Width(Pipe Siz	1											
Depth	5	5' b/c in-between 4' and 6'										
Conversation	974.07407	Cubic Yards										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
974.0740741	583	1.67079601										
Labor Hours:	Productivity											
974.0740741	0.027	26.3										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 2,435												
O&P												
Total O&P * Quantity												
$ 3,098												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 3,252												
Inflation between 2009 to 2014												
$ 3,610												

Appendix Table 76

Backfill of Trench												
3100	Backfill Trench with F.E. loader, wheel mtd, with 2-1/4 C.Y. bucket											
Filling in 5' deep trench with 12" municipal water pipe laid in for 5 miles												
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-10T	32.98	36.28	38.1	57.77	150	0.08	Loose Cubi	0	3.05	2.64	5.69	7.5
Quantity Needed												
Length	5280	Miles										
Width(Pipe Siz	1											
Depth	5	5' b/c in-between 4' and 6'										
Conversation	977.77778	Cubic Yards										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
977.7777778	150	6.518518519										
Labor Hours:	Productivity											
977.7777778	0.08	78.22222222										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 5,564												
O&P												
Total O&P * Quantity												
$ 7,333												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 7,700												
Inflation between 2009 to 2014												
$ 8,547												

Appendix Table 77

Engineering, Permits, Planning				
*assume 5 miles				
Quoted $150 per foot				
will cover Permits, Engendering, Planning, and Contingency				
5280	Feet in 5 miles			
$ 792,000				

Appendix Table 78

Digging the Wells												
Digging of wells 4" to 6"												
Assuming 2 100 ft wells to be drilled												
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-23	69.36	76.33	32	49.62	120	0.333	Linear Feet	0	10.65	23	33.65	42
Quantity Needed												
Conversation	200	0		2 100 foot wells								
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
200	120	1.666666667										
Labor Hours:	Productivity											
200	0.333	66.6										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 6,730												
O&P												
Total O&P * Quantity												
$ 8,400												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 8,820												
Inflation between 2009 to 2014												
$ 9,790												

Appendix Table 79

Installation of Pumps												
Installation of a 5 H.P. submersible motor in the 2 new wells												
Assuming 2 100 ft wells to be drilled												
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
Q-22	24.02	26.43	40.48	61.16	1.14	14.035	Pumps	2775	615	675	4065	4725
Quantity Needed												
Conversation	2	0		2 100 foot wells								
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
2	1.14	1.754385965										
Labor Hours:	Productivity											
2	14.035	28.07										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 8,130												
O&P												
Total O&P * Quantity												
$ 9,450												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 9,923												
Inflation between 2009 to 2014												
$ 11,014												

Appendix Table 80

Electricity of Pumps								
				The costs of pumping water can be calculated as				
Assume		*$C = 0.746 Q h c / (3960 \mu_p \mu_m)$*			*(1)*			
		where						
C		*C = cost per hour*						
	10.5875	*Q = volume flow (gpm)*						
	100	*h = head (ft)*						
	0.0953	*c = cost rate per kWh*						
	0.6	*μ_p = pump efficiency*						
	0.788	*μ_m= motor efficiency*						
	0.0402024	*Cost per hour*						
	2	*Number of Pumps*						
	0.0804049	*Total Per Hour*						
Using Commercial 2014								
PA is	9.53	cents per KwH						
GPM for wells			* assume 8 hr of well production					
Average GPD	10164		**Assume only 15% of that water gets to					
well now is								
100 gpm so	0							
So need wells t	10164							
GPM needed	21.175							
Divided up fron	10.5875	Needed per well						
Hours of operation of well								
Nursery will not get any water from the well on site so will put wells away and pipe water back								
Then gph of the wells is 2700								
Then divide the 20,000 it need to cover by the 2700 to get								
8	hours in growing season							
We assume this is used on average for the entire growing seasons (7 month)								
The other 5 months would be at a rate of 10% of the growing months								
1680	Hours in the growing season							
120	Hours in non-growing season							
1800	Total hours yearly							
otal Cost for Electric to pump								
$ 145	Cost for electricity to pumps							

Appendix Table 81

Running of Electricity		
Assume that wells are 1 mile away		
Cost to run electricity out to new spot		
feet in mile	5280	
Amount of outdoor wiring		
to be buried with the piping		
Price	182	
Length	250	
Needed Units	21.12	
Total	$ 3,844	

Appendix Table 82

Outlets for Wells 1 mile away												
Rainproof 3P 4W 120/ 208V		Digging of Trench for Municipal Pipe at 4' to 6'										
Three Wells												
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
2 Elec	54.11	59.52	37.08	56.48	1.6	10	Each	2025	470	0	2495	2950
Quantity Needed												
Conversation	3	each										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
3	1.6	1.875										
Labor Hours:	Productivity											
3	10	30										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 7,485												
O&P												
Total O&P * Quantity												
$ 8,850												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 9,293												
Inflation between 2009 to 2014												
$ 10,315												

Nursery H:

Nursery H has been a family operated business since 1945 and is located on top of a mountain in the ridge and valley area of Pennsylvania with 27 acres available. The nursery has eight to ten employees, with the owner being the only full time member. There is no well water on site due to the elevation and location of the business. The water is supplied by the local municipality, but this water source is not often used. The water from the municipality acts more as an insurance policy for the site, in case an unforeseen circumstances, such as a drought.

The operation uses recycled irrigation water to tend to their container plots. A majority of the land is a field grown nursery with a small portion dedicated to container grows. Rain water irrigates a most of the land; however, there are two ponds located on the property so they are able to recycle. The ponds were built in the 1980's by the owner. The partial budget will be separated into two distinct options; the defenders, to recapture/recycling, and the challenger, to drilling of additional wells. The defender costs encapsulate dyes, dredging, digging of the recapture pond, and the opportunity cost of the pond. The challenger option is comprised of the opportunity cost of the buffer pond, digging of the buffer pond, and the rates for city water from its operational water meter. The Partial Budget Table H outlines the areas of costs and how they are related.

Partial Budget Table H

Partial Budge Table: Nursery H				
Defender			Challenger	
Recapture/Recycling of Water			Digging of Wells	
Additional Costs			*Additional Returns*	
Dye[151]	$511		Reserve or Buffer Capacity[152]	$ 7,581
Dredging Ponds[153]	$ 1,284			
Digging of Recapture Pond [154]	$34,275			
Reduced Returns			*Reduced Costs*	
Opportunity Cost for Ponds[155]	$10,648		Cost of MW based on uses[156]	$ 7,197
			Digging of Buffer Pond[157]	$7,232
Total	$ 46,719		Total	$ 22,397
	Net Difference	24,322		

The location of the land did not need to be recontoured because it already allowed for a large recapture. The upper pond is 100 feet by 40 feet and lower is 150 feet by 50 feet, both have a depth of 8 feet each. The upper pond is connected to a pump for irrigation and is fed by the lower pond through a siphon system. This allows for a large amount of water to be stored on site. If a drought or shortage is present, the reserve can be supplemented by the municipal water on site. Therefore, the municipal water acts as a security for the farm by providing a ready source of water. The digging out of the

151 Used to combat algal growths in the pond at an assumed rate of every 3 weeks for 26 weeks
152 The reserve proportion of the buffer pond was found by comparing the needed reserves and the capacity currently
153 Assumed dredging every 15 years on the entire pond (is based upon square footage of the pond)
154 Assume 92,000 square feet of area dug out for pond
155 Costs relating to the forgone growing area the pond takes on
156 The rate for municipal water given the usages per year
157 Assume 20,400 square feet of area dug out for pond

recapture pond would cost $546,990 for a pond area of 92,000 square feet, and annualize out $34,275 (Homewyse, 2015).

This farm does not worry about disease as much as others featured in the study. The owner only believes that there are 3% losses due to infected plants in the nursery. Therefore, there are no filtration or sterilization systems in place to combat water borne pathogens. The owner also decided to shy away from varieties of plants that are more susceptible to water borne diseases. There are other concerns with the water on site, such as algal blooms in the ponds. The ponds become full of fertilizer from ozmocote runoff. The alga becomes a problem due to clogging of irrigation pipes and the siphon in between ponds. Nursery H does not use bubblers or agitators, but instead uses relatively inexpensive dyes to combat the algal problem.

The state does not see large issues with water effluent reaching other streams. This is a much different tone to water safety than what other states implement. Nursery H has a spillway for the water to exit the property down the mountain and reach a local river.

Assuming, the afore mentioned state of the nursery, the partial budget should be rather straightforward and simple. The additional cost was the dredging of the ponds which is assumed to occur every 15 years. A dredging of ponds of this size costs $14,375 based on the rule of thumb of $1.25 per square foot, which is amortized based upon the average dredging schedule to be $1,284 annually (Donahoe, 2015). The dyes are only used in the spring and summer due to the need to mitigate the algae when it occurs. The cost per gallon jug is $59 and one gallon covers four acres/foot, the pond is three acres

(Aquatic Biologists, 2014a). The amount of treatments for every three weeks would be about nine treatments; bringing the total to $511.

The reduced returns are just the opportunity cost of the space occupied by the pond. This, as stated previously, is the area of the pond and the price the owner would pay for additional land in the area. Thus, the opportunity cost of the pond is $10,648 indicated by the price of $0.12[158] per square feet and the area of the pond being 92,000 square feet.

The buffer is based upon the needed reserves from the nursery in case of a power outage where there is no way to extract water. The way amount for the buffer pond was found using the number of gallons needed for seven days of watering then dividing the total amount of gallons in the pond by the buffer to get a proportion. The value of the opportunity cost was that of the total initial pond was then multiplied by the proportion to get the overall value of the buffer pond. This is due to the large capacity which the Nursery H pond has at its disposal. Pond proportion for the nursery was .712[159] which when multiplied by the value of the buffer pond of $7,581 for Nursery H. The cost of digging of the buffer pond with an area of 20,400 costs $115,407, with an annual cost of $7,232 (Homewyse, 2015).

The reduced costs correspond to the municipal water in the area. The meter is already in place and we can assume the water availability fee is already paid as well. Thus, the only cost associated with this is the actual price of the water and the monthly meter fee. It is assumed that there is a three inch meter on site. It is assumed that the output needed per a normal growing day is 70,000 gallons per day; thus the total yearly

[158] From Calculations regarding to the Cultice Survey results (2013)
[159] See Appendix C for Proportion Table

amount used is 1,680,000 gallons. This is based upon seven months of maximum usage and five months of slower usages. The county has a base rate of $49.40 every two months, including the first 5,000 gallons used; after the first 5,000 the usage rate is $6.15 per extra 1,000 gallons (Conemaugh Township Municipal Authority, 2014). Therefore the total cost is $7,197 per year. There is not a meter charge indicated for the municipality, therefore there is no cost associated for the nursery.

The total cost for the defender, or recapture/ recycling option is $46,719, while the total for the challenger is $22,397 for increased use of well water. Thus the net savings in relation to using the municipal water would be $24,322. This large discrepancy in the numbers could be explained by the hefty cost of digging out the recapture pond.

Discussion for Nursery H:

Nursery H comprises a nursery with an interesting distinction as it relates to the other nurseries within the study. The nursery does not foresee any real problem with regard to irrigation water besides algal growths within the water. The largest concern with that being the clogging or the pump and irrigation pipes. As stated previously the nursery is only facing 3% losses as they relate to the ornamental crops. That being said the owner see the investment in such preventative measures as overly costly relative to the perceived gains from such an investment. This makes sense for the relative size of the nursery. The nursery is so small that the outlays for such equipment may not be applicable for possible 3% gain in pathogen remediation. The water in the area seems to be at a small risk to such factors as they pertain to pathogen losses.

However, there could be future problems related to the water quality in the region due to other industries not related to horticulture. The fracking industry uses large amounts of water which may contaminate future water resources. The nursery is in an advantageous area and is concerned about projecting its image as a concern about the environment and being locally grown. Therefore, the use of recapture and recycling fulfills a dual purpose, saving water and increasing the perception of the nursery from a marketing standpoint.

Calculations for Nursery H:

Appendix Table 83

Dyes		(Yearly costs)	
1 gallon = 4 acres/foot			
Lake/pond is about 3 acres			
Use about a gallon every few weeks from spring to fall			
Number of weeks for spring and summer			
	26		
With a 1 gallon jug costing			
	$59.00		
Every 2 weeks costs			
	13	weeks	
	$767.00		
Every 3 weeks costs			
	8.66666667	weeks	
	$511.33		
*assume every three weeks			

Appendix Table 84

Dredging				
Assume it costs $1.25 per square foot				
$ 1.25				
Estimated square footage of the ponds based on google map distance tool				
Square footage				
11500				
$ 14,375				

Appendix Table 85

Water Uses					
Ponds create have a capacity of 92000 Cubic Feet of water					
Gallons per cubic Foot					
7.48					
Total gallons Capacity					
688,160					
Average Days of Irrigation if at full capacity					
9.83					
About 10 Days					
If we assume a 80% capture (as indicated by the owner)					
550,528.0	Needed Municipal water every 10 days)				
The estimated water used on the farm annually is					
1,440,000.0					
If the 365 day year is divided by the 10 day cycle of recapture then					
36.5	cycles per year				
And if at each cycle it is assumed that					
550,528.0	is taken from the municipality additionally then if recapture did not occur				
Total water would be cycles*municipality per cycle					
1,440,000.0	gallons				

Appendix Table 86

Water Rates			
Township Extension			
Base Rate = $49.40/2 mo. including first 5,000 gallons used.			
Usage Rate = $6.15/1,000 gallons used			
Estimated need per 2 months is			
1,680,000.0	Total Need		
280,000.00	Amount Every 2 Months		
Cost for first 5,000 gallons			
$ 49			
Cost for rest of water			
275,000.00			
$ 1,741	Per two months		
$ 10,444	Annually (2 month cost*6)		

Appendix Table 87

	Table of his water uses based upon a 3in pipe running 4-5 hours a day				
	Assume 6f/s	Assume 12f/s	Assume 18f/s		
hours	Low	Average	High		
4	33,600	65,400	102,600		
4.5	37,800	73,575	115,425		
5	42,000	81,750	128,250		

Synthetic Small and Large Nurseries:

Unfortunately there are no case studies in this paper that properly outline the budget of a nursery that is thinking about transitioning from a non-recycling irrigation position to one of recapture/recycling. A synthetic example of two hypothetical nurseries which would experience the requisite characteristic was completed. The two nurseries are different in their size at which they operate; one small capacity and In order t construct two new budgets for these hypothetical assumptions were made as they relate to the way the nurseries were assembled. This portion of the construction was very influenced by the results from the Cultice(2013) thesis.

The numbers from the Cultice thesis were initially constrained so there could be some characterization of what a hypothetical nursery would appear as. First, all nurseries which recycled or recapture were omitted from the spreadsheet. Next the remaining group was constrained based upon their answer to the revenue question. Which was used as the indicator of which set the nurseries would belong, either small or large, as the analysis continued? The line of demarcation was at 5, or had a revenue of $500,001 or greater. Any nursery with a revenue greater than $500,000 was considered large, and likewise any nursery with a revenue less than or equal to $500,000 was deemed to be a small nursery. Nurseries that did not answer the revenue question were omitted from further analysis as there would be no way to characterize them. The amount of small nurseries who did not recapture and recycle number 160 operations while he number of large nurseries that did not recapture and recycle number only 35.

Small Nurseries:

The characteristics for the small nurseries are as follows: The majority of water supplied is through the use of wells; 120 out of 160 indicated wells as the primary mode of irrigation. Of the 120 operations 92% of the irrigation supplied is done through wells water. Of the 160 nurseries135 of them indicated that they use between 0 and 100,000 gallons per day. After weighting the responses to include the midpoints of the uses and multiplying them by the number of nurseries in that category, the groups were then summed and the total average of that number was 55,036 gallons per day. . The average gallons per year are 12,383,100 based on the assumed uses in winter and summer. The average acres of the 160 nurseries summarized to 13.612 acres as using the midpoint and averaging out total area. Some nurseries put a different unit area in the wrong column and this was accounted for as the analysis continued. Of the 160 nurseries very few used water pathogen mitigation techniques for their water; therefore, no techniques will be used for the defender side of the budget. From the revenue perspective it is assumed that the nursery would make $104,297. The partial budget will be separated into two distinct options; the defenders, relating to drilling for irrigation water, and the challenger, relating to recapture and recycling of irrigation water. The defender costs encapsulate drilling the wells, purchase and installation of pumps, electricity for wells, permits for the wells, and the digging of the buffer pond. The challenger option is comprised of the opportunity cost of the irrigation pond, chlorination system and smart valve, chlorine gas, digging of the recapture pond, and dredging. The partial budget 3.MS outlines the areas of costs and how they are related.

Partial Budget Table I

Partial Budget Table: Small Synthetic Nursery			
Defender		Challenger	
Drilling of wells		Recapture/Recycle	
Additional Costs		*Additional Returns*	
Digging of wells[160]	$8,290	Opp. Cost Recapture pond[161]	$5,368
Pumps and Install[162]	$860		
Electricity for wells[163]	$842		
Permits for wells[164]	$120		
Digging of Buffer Pond[165]	$818		
Reduced Returns		*Reduced Cost*	
Opp. Cost Buffer pond[166]	$993	Chlorine system[167]	$179
		Smart Valve[168]	$670
		Chlorine gas[169]	$1,540
		Recontouring[170]	$6,506
		Digging of the Pond[171]	$13,771
		Dredging[172]	$5,178
Total	$11,923	Total	$33,212
Net Total	($21,289)		

The number of wells was determined by assuming that new wells could produce 20 gallons per minute, which totals 1,200 gallons per hour if it is assumed that the total hours of irrigation are 8 hours a day. The needed gallons per day are 55,036 based upon

[160] Digging of 6, 4" to 6", 500 foot wells
[161] Costs relating to the forgone growing area the pond takes on
[162] Installation of 6 submersible pumps for the wells
[163] Electricity for the 6 submersible pumps for an entire year based upon the needed gallons and output of the wells
[164] Basic permits for the wells in the state of Maryland
[165] Assume a buffer pond of 2,543 square foot area to dig
[166] The reserve proportion of the buffer pond was found by comparing the needed reserves and the capacity currently
[167] The chlorine system is used to inject chlorine gas into the water passing through for irrigation purposes
[168] Used to regulate the amount chlorine injected for different growing zones
[169] Assumed chlorine gas used to get 2ppm based upon the water needed
[170] Assumed recontoured 75% of the total 13.612 acres of the property
[171] Assumed a recapture pond of 46,382 square foot area
[172] Assumed dredging every 15 years on the entire pond (is based upon square footage of the pond)

weighted responses. Thus it can be assumed that 6 separate wells would need to be dug for the irrigation. The digging of the (6) 500 foot wells came to a total of $132,300, and was amortized over 30 years to a total of $8,290. The pumps purchase and installation were assumed from the LCB[173]. The total amount of the pumps to be installed is 6 pumps ever 10 years is $7,245, which when amortized for 30 years accounts for $860 a year. The normal permits for basic regulations account for $1,910 totaling $120 annually when amortized.

The remaining cost for the wells remains in the electricity needed for the pumps. The rate of electricity is $0.1087 per kWh and cost $0.47 per hour for all 6 pumps to be run; thus the total cost of electricity for all pumps amounts to $842 (U.S. Energy Information Administration, 2014). Another cost was the digging of the buffer pond which would be an area of 2,543 square feet, costing $13,053, and annualized to $818 over thirty years (Homewyse, 2015).

The pond and buffer pond are two important aspects of this budget. First, it is important to understand the size of a pond based upon the need for recapturing of water. This was found by analyzing the percentage of area of which a nursery pond takes out of the growing area.

Appendix Table 88

[173] (Spencer & Babbitt, 2008)

Percent of Pond Relative to Area						
Nursery	Area of Pond	Revenue Group	Arce of Farm	Sq Ft of Farm	Proportion	
A	n/a	2	2	87120	N/A	
B	187,041	12	100	4356000	4.29%	Large
C	874,937	12	400	17424000	5.02%	9.91%
D	4,560	8	22	958320	0.48%	Small
E	309,694	10	105	4573800	6.77%	7.82%
F	85,883	5	50	2178000	3.94%	
G	84,877	8	5	217800	38.97%	
H	92,000	3	27	1176120	7.82%	

As seen from the table above the percentage of land used from small nurseries visited is 7.82%. Therefore, with the size of the farm being 13.612 acres the pond would be just over 1 acre. If a depth of 8 feet is assumed for the pond; the total cubic capacity of the pond would be 55,036 cubic feet of water. The conversion from cubic feet to gallons is 7.48 gallons per cubic foot hence the pond would hold 2,775,669 gallons of water. Consequently the proportion of buffer pond to recapture pond is (55,036*7)/2,775,669 produces a .1387 value. Digging of the recapture pond, with a size of 46,382 square feet, costing $219,775 and annualized to 13,771 yearly (Homewyse, 2015).

Assuming that the area of the recapture pond is about 1 acre the forgone profit can be calculated using the profit per acre of similar nurseries. It is assumed that the small nursery example falls into the 4th grouping category. Thus the forgone profit per square foot is $0.12[174] with a square footage of 46,382. Multiplying these two numbers together gleans the forgone profit of the hypothetical pond in the small nursery example at $5,368. In order to find the forgone profit of the buffer pond one must return to the proportion

[174] From Calculations regarding to the Cultice Survey results (2013)

found earlier, multiplying $5,368 by .1850[175] value yielding a total opportunity cost of $993.

The recapture/recycler option is related to the use of a chlorination system at $2,000 and a smart value, at $7,500 (Regal Chlorinators, 2014). The amortized costs of the chlorination system and smart valve were $179 and $670 respectively. The cost of chlorine gas was $1,540 based upon the needed usage of 2 parts per million (Advanced Specialty Gases, 2014).

The recontouring of the nursery was an important aspect of all nurseries visited in the study. It is assumed that 75% of the land was recontoured at about 10.2 acres. The total cost for recontouring is $103,828[176] and encompasses both hauling and grading of the land, as a similar sized nursery regraded at 10,170 per acre. The amortization of this total over 30 years amounts to $6,506 per year. The final cost is associated with dredging the pond which occurs every 15 years. The total was $57,977 based upon the $1.25 per square foot and the assumed size of the pond; consequently when amortized over 15 years the total is $5,178 (Donahoe, 2015).

The total cost for the challenger, or recapture/ recycling option is $33,212, while the total for the defender is $11,923 for increased use of well water. Thus the net savings in relation to the using the well water would be $21,289. It should be noted this is merely a hypothetical and not a true nursery which was visited, but indicates how profitable a nursery with access to cheap ground water can be.

Calculations for the Small Synthetic Nursery:

Appendix Table 89

[175] See Appendix C for Proportion Table
[176] (Spencer & Babbitt, 2008)

Feet per well	500											
Digging of Wells												
Digging the Wells												
Digging of wells 4" to 6"												
Assuming 2 100 ft wells to be drilled												
Well needed	6.00											
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-23	69.36	76.33	32	49.62	120	0.333	Linear F	0	10.65	23	33.65	42
Quantity Needed												
Conversation	3000	0										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
3000	120	25										
Labor Hours:	Productivity											
3000	0.333	999										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 100,950												
O&P												
Total O&P * Quantity												
$ 126,000												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 132,300												

Appendix Table 90

Installation of Pumps												
Installation of the Pumps												
Installation of a 1 H.P. submersible motor in the 6 new wells												
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
Q-1	0	0	43.88	65.85	2.29	6.987	Pumps	615	305	0	920	1150
Quantity Needed												
Conversation	6	0										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
6	2.29	2.62008734										
Labor Hours:	Productivity											
6	6.987	41.922										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 5,520												
O&P												
Total O&P * Quantity												
$ 6,900												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 7,245												

Appendix Table 91

Electricity of Pumps				
		The costs of pumping water can be calculated as		
1 hp motor				
Assume		$C = 0.746\ Q\ h\ c\ /\ (3960\ \mu_p\ \mu_m)$ (1)		
		where		
C		*C = cost per hour*		
	18	*Q = volume flow (gpm)*		
	100	*h = head (ft)*		
	0.1087	*c = cost rate per kWh*		
	0.6	*μ_p = pump efficiency*	1080	
	0.788	*μ_m = motor efficiency*	7.22E-05	Cost of extraction of 1 gallon of water
	0.07795935	*Cost per hour*		
	6	*Number of Pumps*		
	0.46775611	*Total Per Hour*		

Using Commercial 2014

MD is 10.87 cents per KwH

* Motor efficiency from http://www.engineeringtoolbox.com/electrical-motor-efficiency-d_655.html

Minimum nominal efficiency

Power (hp)	Minimum Nominal Efficiency[1)]
1-4	78.8
5-9	84
10-19	85.5
20 - 49	88.5
50 - 99	90.2
100 - 124	91.7
> 125	92.4

Where electricity is available, it is the most efficient power source. As shown in Table 1 on page 4, the efficiency of electric motors ranges from 80 percent for motors under 7.5 horsepower to over 90 percent for motors of 75 horsepower or larger. One disadvantage of electrical systems is that electric lines in many rural areas do not run near the water source, and three-phase power is often less available in these areas. Most electric companies require three-phase power

Electric Motor Size (horsepower)	Full Load Motor Efficiency (percent)	Typical Attainable Matched Size Pump Efficiency* (percent)	Pumping Plant Efficiency** (percent)
3-5	80 - 86	55 - 65	44 - 56
7.5 - 10	85 - 89	60 - 70	51 - 62
15 - 30	86 - 90	65 - 75	56 - 68
40 - 60	88 - 92	70 - 80	62 - 74
75 and larger	90 - 93	75 - 85	68 - 79

Hours of operation of well

8 hours in growing season

We assume this is used on average for the entire growing seasons (7 month)

The other 5 months would be at a rate of 10% of the growing months

1680	Hours in the growing season
120	Hours in non-growing season
1800	Total hours yearly

otal Cost for Electric to pump

$ 842 Cost for electricity to pumps

Appendix Table 92

Permit For Well						
			Cost	Life of Permit	number of wells	
			May not exceed		6	
3.14	Well Construction Permit		160			
	Water Appropriation and		No Fee			
3.15	Use Permit					
	Ground water discharge					
3.05	Permit					
	Erosion/Sediment Control		No Fee	No Expiration		
3.21	and Storm water					
	General Permit for Storm		less than 10 acres			
3.23	water Associated with		100			
			250-450			
3.28	Well Drillers License		350			
Total for	1910					
permits						

Appendix Table 93

Area of Pond				
13.612	Area of nursery			
7.82%	Portion dedicated to recapture pond			
1.064775703	Area of the pond			
46,382	Area of the pond is sq ft			
6	Assumed depth in ft			
278,290	Cubic feet of pond			
7.48052	Gallons in a cubic foot of water			
2,081,752	Total gallons for capacity			
			Proportion	
		Opportunity	for Needed	Buffer Opp
		Cost in $	Reserves	Cost
Synthetic Sma	SS	$ 5,368	0.1850614	$ 993.45

Appendix Table 94

		Cost per Acre from		
Cost per acres of Regrading		Similar Sized Nursery		Total
Acres	10.21	$	10,170	$ 103,828
	$ 32,491			

Appendix Table 95

Dredging					
Assume it costs $1.25 per square foot					
$ 1.25					
Estimated square footage of the ponds based on google map distance tool					
Square footage					
46381.62963					
$ 57,977					
Years between dredge					
15					

Large Nurseries:

The characteristics for the large nurseries are as follows: Of the 36 operations 61% were exclusively wholesale nurseries. It will be assumed that wells will be used again to keep the two hypothetical situations consistent with one another. The average acres of the 36 nurseries summarized to 88.92 acres as using the midpoint and averaging out total area. Some nurseries put a different unit area in the wrong column and this was corrected for as the analysis continued. Weighting of the total irrigation used for the nurseries led to an estimate of 232,258 gallons per day; which is somewhat constant with nurseries of similar size. The average gallons per year are 52,258,050 on the assumed uses in winter and summer. Of the 36 nurseries very few used water pathogen mitigation techniques for their water; therefore, no techniques will be used for the defender side of the budget. From the revenue perspective it is assumed that the nursery would make $2,027,778. The partial budget will be separated into two distinct options; the defenders, relating to drilling for irrigation water, and the challenger, relating to recapture and recycling of irrigation water. The defender costs encapsulate drilling the wells, purchase and installation of pumps, electricity for wells, permits for the wells, and the buffer pond. The challenger option is comprised of the opportunity cost of the irrigation pond, chlorination system and smart valve, chlorine gas, digging of the pond, and dredging. The partial budget 3.ML outlines the areas of costs and how they are related.

Partial Budget Table J

Partial Budget Table: Large Synthetic Nursery		
Defender		Challenger
Digging of Wells		Recapture/Recycling of Water
Additional Costs		***Additional Returns***

Digging of wells[177]	$34,542		Recapture pond[178]	$50,491
Pumps and Installation[179]	$3,584			
Electricity for wells[180]	$3,508			
Permits for wells[181]	$429			
Digging of Buffer Pond[182]	$3,449			
Reduced Returns			*Reduced Cost*	
Buffer pond[183]	$3,573		Chlorine system[184]	$179
			Smart Valve[185]	$670
			Chlorine gas[186]	$6,497
			Recontouring[187]	$314,168
			Digging of the Pond[188]	$123,328
			Dredging[189]	$42,865
Total	$50,276		Total	$328,942
	Net Total	($278,666)		

The number of wells was determined by assuming that new wells could produce 20 gallons per minute, yielding 1,200 gallons per hour while also assuming that the total hours of irrigation are 8 hours a day as needed. The needed gallon per day is 232,258

177 Digging of 25, 4" to 6", 500 foot wells
178 Costs relating to the forgone growing area the pond takes on
179 Installation of 25 submersible pumps for the wells
180 Electricity for the 25 submersible pumps for an entire year based upon the needed gallons and output of the wells
181 Basic permits for the wells in the state of Maryland
182 Assume10,733 square foot area dug for pond
183 The reserve proportion of the buffer pond was found by comparing the needed reserves and the capacity currently
184 The chlorine system is used to inject chlorine gas into the water passing through for irrigation purposes
185 Used to regulate the amount chlorine injected for different growing zones
186 Assumed chlorine gas used to get 2ppm based upon the water needed
187 Assumed recontoured 75% of the total 88.92 acres of the property
188 Assume383,930 square foot area dug for pond
189 Assumed dredging every 15 years on the entire pond (is based upon square footage of the pond)

based upon weighted responses. Thus it can be assumed that 6 separate wells would need to be dug for the irrigation. The digging of the (25), 500 foot wells came to a total of $551,250, and were amortized over thirty years to a total of $34,542. The pumps purchase and installation were assumed from the LCB[190]. The total amount of pumps to be installed is twenty-five pumps every 10 years costing $30,188, which when amortized for thirty years accounts for $3,584 a year. The normal permits for basic regulations accounts for $6,850 meaning when amortized totals $429 annually. The remaining costs regarding the wells amount to the electricity needed for the pumps. The rate of electricity is $0.1087 per kWh and cost $1.95 per hour for all 25 pumps to be run (U.S. Energy Information Administration, 2014). Thus the total cost of electricity for all pumps amounts to $3,508. An additional cost is implied with the digging of the buffer pond which. would be an area of 10,733 square feet, costing $55,035, and annualized to $3,449 over thirty years (Homewyse, 2015)

The pond and buffer pond are two important aspects of this budget. First it is important to understand the size of a pond based upon the need for recapturing of water. This was found by analyzing the percentage of area of which a nursery pond takes out of the growing area.

Appendix Table 96

[190] (Spencer & Babbitt, 2008)

Percent of Pond Relative to Area						
Nursery	Area of Pond	Revenue Group	Arce of Farm	Sq Ft of Farm	Proportion	
A	n/a	2	2	87120	N/A	
B	187,041	12	100	4356000	4.29%	Large
C	874,937	12	400	17424000	5.02%	9.91%
D	4,560	8	22	958320	0.48%	Small
E	309,694	10	105	4573800	6.77%	7.82%
F	85,883	5	50	2178000	3.94%	
G	84,877	8	5	217800	38.97%	
H	92,000	3	27	1176120	7.82%	

As seen from the table above the percentage of land used from small nurseries visited is 9.91%. Therefore, with the size of the farm being 88.92 acres the pond would be 8.8 acres. If a depth of 8 feet is assumed for the pond; the total cubic capacity of the pond would be 3,071,601 cubic feet of water. The conversion from cubic feet to gallons is 7.48 gallons per cubic foot, which means the pond, would hold 22,977,175 gallons of water. Thus the proportion of buffer pond to recapture pond is (232,258*7)/22,977,175 producing a .0708 value.

Assuming that the area of the pond is 8.8 acres the forgone profit can be calculated using the profit per acre of similar nurseries. It is assumed that the small nursery example falls into the 7 to 12 grouping category. Thus the forgone profit per square foot is $0.13[191] with a square footage of 383,950. Multiplying these two numbers together gleans the forgone profit of the hypothetical pond in the small nursery example at $50,491. Returning to the proportion found earlier can be multiplied by the perceived forgone profit. Thus $50,491 multiplied by the .0944[192]value to get the forgone profit of the buffer pond is $4,764.

[191] From Calculations regarding to the Cultice Survey results (2013)
[192] See Appendix C for Proportion Table

The recapture/recycler option is related to the use of a chlorination system, at $2,000 and a smart value, at $7,500 (Regal Chlorinators, 2014). The amortized costs of the chlorination system and smart valve are$179 and $670 respectively. The cost of chlorine gas was $6,497 based upon the needed usage of 2 parts per million (Advanced Specialty Gases, 2014).

The recontouring of the nursery was an important aspect of all nurseries visited in the study. It is assumed that 75% of the land was recontoured or about 66.7 acres. The total cost for recontouring is $1,674,258[193] and encompasses both hauling and grading of the land, as a similar sized nursery regraded at 25,105 per acre. The amortization of this total over 30 years amounts to $104,912 per year. The total was $479,938 based for dredging upon the $1.25 per square foot and the assumed size of the pond; thus when amortized over fifteen years the total is $42,865 (Donahoe, 2015). Cost of digging out the recapture pond is not insignificant as it would require $1,968,168 for a 383,950 square foot pond to be dug, with a yearly cost of $123,328 annually (Homewyse, 2015).

The total cost for the challenger, or recapture/ recycling option is $328,942, while the total for the defender is $50,276 for the increased use of well water. Thus the net savings in relation to the use of the well water would be $278,666. It should be noted this is merely a hypothetical and not a true nursery which was visited, but highlighted how a nursery with access to water could be profitable without recycling irrigation water.

Calculations for the Small Synthetic Nursery:

Appendix Table 97

[193] (Spencer & Babbitt, 2008)

Feet per well	500											
Digging the Wells												
Digging of wells 4" to 6"												
Assuming 2 100 ft wells to be drilled												
Wells needed	25.00											
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
B-23	69.36	76.33	32	49.62	120	0.333	Linear Fe	0	10.65	23	33.65	42
Quantity Needed												
Conversation	12500	0		3 100 foot wells								
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
12500	120	104.16667										
Labor Hours:	Productivity											
12500	0.333	4162.5										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 420,625												
O&P												
Total O&P * Quantity												
$ 525,000												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 551,250												

Appendix Table 98

Installation of Pumps												
Installation of the Pumps												
Installation of a 1 H.P. submersible motor in the 25 new wells												
Crew	Equip Cost Bare	Equip Cost O&P	Crew Cost Bare	Crew Cost O&P	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total O&P
Q-1	0	0	43.88	65.85	2.29	6.987	Pumps	615	305	0	920	1150
Quantity Needed												
Conversation	25	0										
Productivity:												
Quantity		Duration										
Crew Days:	Daily Output											
25	2.29	10.917031										
Labor Hours:	Productivity											
25	6.987	174.675										
Bare Costs:												
Materials:												
Bare Materials		*Assuming Linear use of material through work time										
Total*Quantity Needed=		*Multiply Material by labor days (due to relationship to daily output)										
$ 23,000												
O&P												
Total O&P * Quantity												
$ 28,750												
Contingency												
Increase Cost for Contingency (5%)												
Contingency Materials:												
Bare Costs*5% for waste and contingency												
$ 30,188												

Appendix Table 99

Electricity of Pumps								
			The costs of pumping water can be calculated as					
1 hp motor								
Assume		$C = 0.746\ Q\ h\ c\ /\ (3960\ \mu_p\ \mu_m)$		(1)				
		where						
C		*C = cost per hour*						
	18	*Q = volume flow (gpm)*						
	100	*h = head (ft)*						
	0.1087	*c = cost rate per kWh*						
	0.6	μ_p *= pump efficiency*		1080				
	0.788	μ_m*= motor efficiency*		7.2E-05	Cost of extraction of 1 gallon of water			
	0.0779594	*Cost per hour*						
	25	*Number of Pumps*						
	1.9489838	*Total Per Hour*						

Using Commercial 2014

MD is 10.87 cents per KwH

Minimum nominal efficiency

Power (hp)	Minimum Nominal Efficiency[1)]
1-4	78.8
5-9	84
10-19	85.5
20 - 49	88.5
50 - 99	90.2
100 - 124	91.7
> 125	92.4

Where electricity is available, it is the most efficient power source. As shown in Table 1 on page 4, the efficiency of electric motors ranges from 80 percent for motors under 7.5 horsepower to over 90 percent for motors of 75 horsepower or larger. One disadvantage of electrical systems is that electric lines in many rural areas do not run near the water source, and three-phase power is often less available in these areas. Most electric companies require three-phase power for motors that

Electric Motor Size (horsepower)	Full Load Motor Efficiency (percent)	Typical Attainable Matched Size Pump Efficiency* (percent)	Pumping Plant Efficiency** (percent)
3-5	80 - 86	55 - 65	44 - 56
7.5 - 10	85 - 89	60 - 70	51 - 62
15 - 30	86 - 90	65 - 75	56 - 68
40 - 60	88 - 92	70 - 80	62 - 74
75 and larger	90 - 93	75 - 85	68 - 79

Hours of operation of well

8 hours in growing season

We assume this is used on average for the entire growing seasons (7 month)

The other 5 months would be at a rate of 10% of the growing months

1680	Hours in the growing season
120	Hours in non-growing season
1800	Total hours yearly

otal Cost for Electric to pump

$ 3,508 Cost for electricity to pumps

Appendix Table 100

Permit For Well						
			Cost	Life of Permit	number of wells	
3.14	Well Construction Permit		May not exceed 160		25	
3.15	Water Appropriation and Use Permit		No Fee			
3.05	Ground water discharge Permit					
3.21	Erosion/Sediment Control and Storm		No Fee	No Expiration		
3.23	General Permit for Storm water Associated		less than 10 acres 100			
3.28	Well Drillers License		250-450 350			
Total for permits	6850					

Appendix Table 101

Area of Pond				
88.92	Area of nursery			
9.91%	Portion dedicated to recapture pond			
8.814282809	Area of the pond			
383,950	Area of the pond is sq ft			
6	Assumed depth in ft			
2,303,701	Cubic feet of pond			
7.48052	Gallons in a cubic foot of water			
17,232,881	Total gallons for capacity			
		Opportunity Cost in $	Proportion for Needed Reserves	Buffer Opp Cost
Synthetic Large	SL	50491.303	0.0943432	$ 4,763.51

Appendix Table 102

Chlorine Systems		
System for chlorination		$2,000.00
Smart-Valve		$7,500.00

Appendix Table 103

		Cost per Acre from		
Cost per acres of Regradin		Similar Sized Nursery		Total Regrade
Acres	66.69	$	25,105	$ 1,674,258
	$ 32,491			

Appendix Table 104

Dredging					
Assume it costs $1.25 per square foot					
$ 1.25					
Estimated square footage of the ponds based on google map distance tool					
Square footage					
383950.1592					
$ 479,938					
Years between dredge					
15					

<u>Discussion for Synthetic Nurseries:</u>

The two synthetics are an example of possible ways in which nurseries that do not recycle may view the decision making process for going to a recapture/recycling operation. There is clear difference from one nursery state to the other. They are very comparable, but as seen from the visits, while the end product may be the same the way that product is produced is vastly different depending on a litany of factors.

The use of these two budgets attempts to show an average nursery which responded to the survey conducted by Cultice(2013). The average nursery with regard to using a traditional source of water is much different from the nursery that recaptures and recycles. One of the largest factors occurs in the pond used for recapture, which is a major outlay of capital and forgone profit that could be realized initially. It should be noted that the partial budget for the two synthetic examples were very simple and crude in conception and execution. The primary purpose was to extrapolate the factors that could affect a nursery's decisions to move to an entirely new business plan. The budget wanted to create real numbers associated with this crude estimate to give readers some sort of anchor or baseline with which to evaluate decisions made. For instance, if the future holds higher water prices then a nursery may need to seriously consider such a move to recapture/recycling operation. If a nursery is already located in an area suitable for recapture the partial budget for that nursery may dictate that a business model shift. Therefore, as stated initially, the synthetic budget should be taken as they are; a small scorecard of basic assumptions of what is currently done and what could be done at a hypothetical nursery. Each nursery is so different in its resources and factors it is difficult to pigeon hole every business into a definitive category.

Appendix Table 105: Digging of Ponds Cost Table:

Digging of Ponds Calculations with Ranges based up Area					
Recapture Ponds			Buffer Ponds		
Nursery B	Low	$ 563,763	Nursery B	Low	$ 352,464
Sq Ft	High	$ 1,341,458	Sq Ft	High	$ 838,774
187,041	Total	$ 952,611	116,970	Total	$ 595,619
Nursery C	Low	$ 2,636,367	Nursery C	Low	$ 104,442
Sq Ft	High	$ 6,273,891	Sq Ft	High	$ 248,544
874,937	Total	$ 4,455,129	34,658	Total	$ 176,493
Nursery D	Low	$ 13,842	Nursery D	Low	$ 33,654
Sq Ft	High	$ 32,941	Sq Ft	High	$ 80,087
4,560	Total	$ 23,392	11,091	Total	$ 56,871
Nursery E	Low	$ 1,067,682	Nursery E	Low	$ 7,593
Sq Ft	High	$ 2,540,814	Sq Ft	High	$ 18,068
309,694	Total	$ 1,804,248	2,199	Total	$ 12,831
Nursery F	Low	$ 278,744	Nursery F	Low	$ 10,134
Sq Ft	High	$ 663,341	Sq Ft	High	$ 24,115
85,883	Total	$ 471,043	3,119	Total	$ 17,125
Nursery G	Low	$ 298,627	Nursery G	Low	$ 7,816
Sq Ft	High	$ 710,655	Sq Ft	High	$ 18,598
84,877	Total	$ 504,641	2,218	Total	$ 13,207
Nursery H	Low	$ 323,687	Nursery H	Low	$ 68,294
Sq Ft	High	$ 770,292	Sq Ft	High	$ 162,520
92,000	Total	$ 546,990	20,400	Total	$ 115,407
S Small	Low	$ 104,706	S Small	Low	$ 7,724
Sq Ft	High	$ 334,843	Sq Ft	High	$ 18,381
46,382	Total	$ 219,775	2,543	Total	$ 13,053
S Large	Low	$ 1,164,683	S Large	Low	$ 32,568
Sq Ft	High	$ 2,771,652	Sq Ft	High	$ 77,502
383,950	Total	$ 1,968,168	10,733	Total	$ 55,035

Appendix B: Sensitivity Analysis Calculations and Tables

Sensitivity Analysis:

The other sensitivity analysis involves the cost of extraction per gallon, relative to wells and municipal water. The results from this section highlight effects on least-cost water source if the price for water extraction increases or decreases. Changes in costs for wells or municipal water sources are estimated depending on the possible challenger source. The electricity price directly affects water extraction costs with regard to wells. The historical electricity prices were found for Maryland, Pennsylvania, and Virginia. These prices were in nominal terms (U.S. Energy Information Administration, 2014). The nominal terms were used to conduct predictive analysis based upon previous time period's prices and the process will be elaborated on shortly. The objective of this analysis is to forecast out future prices to allow owners to assess possible price changes into the future. These projections are dependent upon the area where the nursery is located and its current resources usages.

The other extraction option was the price of water from public sources. The water prices were needed for five of the eight nursery case studies; three from Virginia, one from Maryland, and one from Pennsylvania. The Virginia water price was found from DAA audits (Draper Aden Associates, 1999-2014). The water prices were obtained from annual water cost reports published for different counties throughout Virginia. Some counties did not report every year and the closest county was used a proxy for that year. Residential prices are charged in 5,000 gallon units. Different counties were used for each municipal water price depending the reporting for that year, on where the county was located and the amount of information available from the utility. The municipal water authorities were contacted but few had relevant prices going back more than five years. The Maryland county provided the percentage increase in water prices since 1999 (Baltimore Public Works, 2015).The municipality for the Pennsylvania nursery provided water prices back to 2006 (Conemaugh Township Municipal Authority, 2014).

The prices for both municipal water extraction and electricity were analyzed in a time series framework to estimate a forecast mean and a 95% confidence level above and below that mean. The team at Virginia Tech's LISA (Laboratory for Interdisciplinary Statistical Analysis) assisted with analysis of these numbers. The team helped to construct models to run in R[194], a statistical program that would predict the future water prices to the year 2019[195] in order to inform the sensitivity analysis. The projections into the future are used to assess possible price fluctuations, based upon past prices. The cost of extraction could then be gleaned from the mean and confidence intervals, which was then related back to the partial budgets.

Predictive modeling was implemented on time series data to get estimates in regard to future pricing. The future pricing data was used in turn with descriptive statistics to show a mean and a 95% confidence interval for each year from 2015 to 2019. Each nursery then has its total gallon usage for the year multiplied by the electricity or municipal water prices to show how the overall expenditure would be influenced by the changes in the price of electricity to run well pumps or municipal water if the primary source was municipal water.

In Table 6-1 the outcome of the partial budgets is shown in relation to the change in the water extraction costs. The total cost of the defender, recapturing and recycling, is shown as well as the total cost of the challenger, either municipal water or well water,

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[194] R: A language and environment for statistical computing, 2008; R Development Core Team (R Development Team, 2010)
[195] The code used is listed in Appendix D for all nurseries and outputs in Appendix C

without the cost of extraction. The cost of extraction is formulated with regard to the cost of extracting well water through an electric motor or the cost of municipal water for the nursery. Accordingly, a new outcome for the partial budget is shown as the defender is compared to the challenger with the extraction costs added to it. The effects of varied costs of extraction are presented for the low 95%, the mean, and the high 95%. This is the 95% indicates that the price will be within the 95% confidence interval of the mean. Each of these options represents a possible future cost to the nursery for the price of water. For instance, the cost of extraction per gallon, found in Appendix C, is multiplied by the number of gallons needed for the nursery over the year. The Total Defender is the entire cost of the defender option from the initial partial budget relating to recycling water. The challenger without water encompasses all costs associated with the alternative to recapturing and recycling with the exception of water costs. Price of either electricity for well water extraction or price for municipal water can change between the mean, lower and, upper costs for each nursery. The costs of water extraction are added to the challenger costs without water and then compared with the defender option to show a new output for the partial budget. The Table 6-1: Sensitivity Analysis of Water Extraction Costs for 2017 below shows possible changes to the partial budget based on changes in water extraction costs.

Table 6-1: Sensitivity Analysis of Water Extraction Costs for 2017

Effect of Water Rate Fluctuation on Nursery Partial Budgets				
2017				
Nursery A				
Total Defender	Water Costs		New Outcome of P.B.	
$4,493	Low 95%	$2,307	Low 95%	$164
Total Challenger Without Water	Mean	$4,383	Mean	($1,912)
$2,021	High 95%	$6,459	High 95%	($3,988)
Nursery B				
Total Defender	Water Costs		New Outcome of P.B.	
$291,322	Low 95%	$725,987	Low 95%	($623,716)
Total Challenger Without Water	Mean	$1,055,880	Mean	($953,609)
$189,051	High 95%	$1,385,774	High 95%	($1,283,503)
Nursery C				
Total Defender	Water Costs		New Outcome of P.B.	
$729,945	Low 95%	$390,386	Low 95%	($252,021)
Total Challenger Without Water	Mean	$466,877	Mean	($328,512)
$591,580	High 95%	$543,369	High 95%	($405,003)
Nursery D				
Total Defender	Electric Costs		New Outcome of P.B.	
$4,377	Low 95%	$427	Low 95%	($3,131)
Total Challenger Without Electric	Mean	$747	Mean	($3,452)
$7,081	High 95%	$1,068	High 95%	($3,772)
Nursery E				
Total Defender	Water Costs		New Outcome of P.B.	
$161,306	Low 95%	$12,429	Low 95%	($111,559)
Total Challenger Without Water	Mean	$14,506	Mean	($113,637)
$260,437	High 95%	$16,583	High 95%	($115,714)
Nursery F				
Total Defender	Electric Costs		New Outcome of P.B.	
$177,870	Low 95%	$937	Low 95%	$168,377
Total Challenger Without Electric	Mean	$1,538	Mean	$167,775
$8,557	High 95%	$2,140	High 95%	$167,174
Nursery G				
Total Defender	Electric Costs		New Outcome of P.B.	
$55,243	Low 95%	$846	Low 95%	($1,289)
Total Challenger Without Electric	Mean	$948	Mean	($1,391)
$55,686	High 95%	$1,050	High 95%	($1,493)
Nursery H				
Total Defender	Water Costs		New Outcome of P.B.	
$46,719	Low 95%	$8,393	Low 95%	$23,125
Total Challenger Without Water	Mean	$11,690	Mean	$19,829
$15,200	High 95%	$14,986	High 95%	$16,532

As seen in Table 6-1: Sensitivity Analysis of Water Extraction Costs for 2017 above, differences can be seen for nurseries in which the extraction option constitutes a large percentage of total costs for that water source. Therefore, these numbers can be related back to the Cost Matrix, from Chapter 4 in that nurseries for which water extraction costs are a large percentage of total costs are more sensitive to changes in water extraction costs. Nursery A would find municipal water a more profitable source if low estimates of future prices of water were true. Switching of the least cost option from the recapture and recycle option to municipal water occurs because of the large proportion of the budget which the cost of municipal water encompasses; therefore, a small change in price would dictate a significant change in the budget.

It should also be noted there is more variance in the results for changes in the water rates than in the electrical rates[196]. The lower prices could be a function of the lower overall cost of electricity, as electricity comprises only 3.4% of the average well water budgets compared to price of municipal water costing 49% of the budget.

It should be noted that the prices used in the table and this analysis are assumed to be under average rainfall and a moderate climate. , A drought; a year with heavy rainfall, or passage of future regulation regarding water extraction could result in more drastic change in the cost of water extraction. n especially rain filled year; or future regulation were passed, the price of water would be subject to drastic change. Accordingly, the costs would be either diminished or exaggerated depending on the event that occurred. The analysis does not take into account these factors.

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[196] Table of extraction costs for one gallon can be found in Appendix C. Nurseries A,B,C,E, and H would use municipal water, and Nurseries D,F, and G would use electric wells.

The results shown are from a two year prediction; yet, predictions up to 2019 are provided in Appendix B. The variance of the confidence intervals increases as the time frame lengthens; consequently, the predictions are subject to more variance. In the 2017 examples, the partial budgets do change significantly at some point. The future water rates have greater fluctuation compared to the electrical prices. Some of the disparities came from the biggest nurseries (B and C). The disparities can be attributed to the large amount of water that the nurseries use; accordingly, when a small change occurs it is magnified over the substantial amount of water used. Sensitivity analysis with regard to the cost of water can be seen as having little or no effect on a majority of the nurseries measured in this project. The only nursery in which the results changed as water extractions costs varied was nursery A, which can be explained by large costs associated with water relative to other outlays in the challenger option. Price of water is not a factor which affects the least cost option in terms of water source.

Price of Water Extraction:

Appendix Table 106: Effect of Water Rate Fluctuation on Nursery Budgets 2015

Effect of Water Rate Fluctuation on Nursery Partial Budgets				
2015				
Nursery A				
Total Defender	Water Costs		New Outcome of P.B.	
$4,493	Low 95%	$2,467	Low 95%	$4
Total Challenger Without Water	Mean	$4,380	Mean	($1,909)
$2,021	High 95%	$6,293	High 95%	($3,821)
Nursery B				
Total Defender	Water Costs		New Outcome of P.B.	
$291,322	Low 95%	$766,310	Low 95%	($664,039)
Total Challenger Without Water	Mean	$1,080,491	Mean	($978,220)
$189,051	High 95%	$1,394,672	High 95%	($1,292,401)
Nursery C				
Total Defender	Water Costs		New Outcome of P.B.	
$729,945	Low 95%	$394,931	Low 95%	($256,566)
Total Challenger Without Water	Mean	$466,502	Mean	($328,136)
$591,580	High 95%	$538,072	High 95%	($399,707)
Nursery D				
Total Defender	Electric Costs		New Outcome of P.B.	
$4,377	Low 95%	$555	Low 95%	($3,259)
Total Challenger Without Electric	Mean	$724	Mean	($3,428)
$7,081	High 95%	$892	High 95%	($3,597)
Nursery E				
Total Defender	Water Costs		New Outcome of P.B.	
$161,306	Low 95%	$11,356	Low 95%	($110,486)
Total Challenger Without Water	Mean	$12,263	Mean	($111,394)
$260,437	High 95%	$13,171	High 95%	($112,302)
Nursery F				
Total Defender	Electric Costs		New Outcome of P.B.	
$177,870	Low 95%	$1,155	Low 95%	$168,158
Total Challenger Without Electric	Mean	$1,538	Mean	$167,775
$8,557	High 95%	$1,921	High 95%	$167,392
Nursery G				
Total Defender	Electric Costs		New Outcome of P.B.	
$55,243	Low 95%	$594	Low 95%	($1,037)
Total Challenger Without Electric	Mean	$653	Mean	($1,096)
$55,686	High 95%	$711	High 95%	($1,154)
Nursery H				
Total Defender	Water Costs		New Outcome of P.B.	
$46,719	Low 95%	$8,321	Low 95%	$23,197
Total Challenger Without Water	Mean	$11,181	Mean	$20,337
$15,200	High 95%	$14,042	High 95%	$17,477

Appendix Table 107: Effect of Water Rate Fluctuation on Nursery Budgets 2016

Effect of Water Rate Fluctuation on Nursery Partial Budgets				
2016				
Nursery A				
Total Defender	Water Costs		New Outcome of P.B.	
$4,493	Low 95%	$2,348	Low 95%	$123
Total Challenger Without Water	Mean	$4,382	Mean	($1,911)
$2,021	High 95%	$6,416	High 95%	($3,945)
Nursery B				
Total Defender	Water Costs		New Outcome of P.B.	
$291,322	Low 95%	$743,930	Low 95%	($641,659)
Total Challenger Without Water	Mean	$1,067,249	Mean	($964,978)
$189,051	High 95%	$1,390,569	High 95%	($1,288,298)
Nursery C				
Total Defender	Water Costs		New Outcome of P.B.	
$729,945	Low 95%	$393,408	Low 95%	($255,042)
Total Challenger Without Water	Mean	$467,247	Mean	($328,881)
$591,580	High 95%	$541,085	High 95%	($402,720)
Nursery D				
Total Defender	Electric Costs		New Outcome of P.B.	
$4,377	Low 95%	$490	Low 95%	($3,195)
Total Challenger Without Electric	Mean	$739	Mean	($3,443)
$7,081	High 95%	$988	High 95%	($3,692)
Nursery E				
Total Defender	Water Costs		New Outcome of P.B.	
$161,306	Low 95%	$11,930	Low 95%	($111,061)
Total Challenger Without Water	Mean	$13,385	Mean	($112,515)
$260,437	High 95%	$14,839	High 95%	($113,970)
Nursery F				
Total Defender	Electric Costs		New Outcome of P.B.	
$177,870	Low 95%	$1,034	Low 95%	$168,280
Total Challenger Without Electric	Mean	$1,538	Mean	$167,775
$8,557	High 95%	$2,043	High 95%	$167,271
Nursery G				
Total Defender	Electric Costs		New Outcome of P.B.	
$55,243	Low 95%	$585	Low 95%	($1,028)
Total Challenger Without Electric	Mean	$651	Mean	($1,094)
$55,686	High 95%	$717	High 95%	($1,160)
Nursery H				
Total Defender	Water Costs		New Outcome of P.B.	
$46,719	Low 95%	$8,393	Low 95%	$23,125
Total Challenger Without Water	Mean	$11,690	Mean	$19,829
$15,200	High 95%	$14,986	High 95%	$16,532

Appendix Table 108: Effect of Water Rate Fluctuation on Nursery Budgets 2017

Effect of Water Rate Fluctuation on Nursery Partial Budgets				
2017				
Nursery A				
Total Defender	Water Costs		New Outcome of P.B.	
$4,493	Low 95%	$2,307	Low 95%	$164
Total Challenger Without Water	Mean	$4,383	Mean	($1,912)
$2,021	High 95%	$6,459	High 95%	($3,988)
Nursery B				
Total Defender	Water Costs		New Outcome of P.B.	
$291,322	Low 95%	$725,987	Low 95%	($623,716)
Total Challenger Without Water	Mean	$1,055,880	Mean	($953,609)
$189,051	High 95%	$1,385,774	High 95%	($1,283,503)
Nursery C				
Total Defender	Water Costs		New Outcome of P.B.	
$729,945	Low 95%	$390,386	Low 95%	($252,021)
Total Challenger Without Water	Mean	$466,877	Mean	($328,512)
$591,580	High 95%	$543,369	High 95%	($405,003)
Nursery D				
Total Defender	Electric Costs		New Outcome of P.B.	
$4,377	Low 95%	$427	Low 95%	($3,131)
Total Challenger Without Electric	Mean	$747	Mean	($3,452)
$7,081	High 95%	$1,068	High 95%	($3,772)
Nursery E				
Total Defender	Water Costs		New Outcome of P.B.	
$161,306	Low 95%	$12,429	Low 95%	($111,559)
Total Challenger Without Water	Mean	$14,506	Mean	($113,637)
$260,437	High 95%	$16,583	High 95%	($115,714)
Nursery F				
Total Defender	Electric Costs		New Outcome of P.B.	
$177,870	Low 95%	$937	Low 95%	$168,377
Total Challenger Without Electric	Mean	$1,538	Mean	$167,775
$8,557	High 95%	$2,140	High 95%	$167,174
Nursery G				
Total Defender	Electric Costs		New Outcome of P.B.	
$55,243	Low 95%	$580	Low 95%	($1,023)
Total Challenger Without Electric	Mean	$650	Mean	($1,093)
$55,686	High 95%	$720	High 95%	($1,163)
Nursery H				
Total Defender	Water Costs		New Outcome of P.B.	
$46,719	Low 95%	$8,393	Low 95%	$23,125
Total Challenger Without Water	Mean	$11,690	Mean	$19,829
$15,200	High 95%	$14,986	High 95%	$16,532

Sensitivity Analysis for Operating Profit for Land

Appendix Table 109: Cost of Land Sensitivity Analysis Table Nursery A[197]

Cost of Land Sensitivity Analysis Table					
Nursery A					
Group	2	Defender without Pond Costs	$4,493	Percent Change from the Baseline	
Pond Area	N/A				
Buffer Area	N/A	Challenger without Buffer Costs	$6,105		
Profit / Sq Foot Ranges Combinations	Profit per Sq Ft.	New Outcome of Partial Budget			Sensitivity Index
Upper / Upper	$0.07	N/A		N/A	N/A
Upper/ Mean	$0.08	N/A		N/A	N/A
Upper/Lower	$0.10	N/A		N/A	N/A
Mean/Upper	$0.06	N/A		N/A	N/A
Mean/Mean	$0.07	N/A		N/A	N/A
Mean/Lower	$0.09	N/A		N/A	N/A
Lower/Upper	$0.05	N/A		N/A	N/A
Lower/Mean	$0.06	N/A		N/A	N/A
Lower/Lower	$0.07	N/A		N/A	N/A

Appendix Table 110: Cost of Land Sensitivity Analysis Table Nursery B

Cost of Land Sensitivity Analysis Table					
Nursery B					
Group	5	Defender without Pond Costs	$266,725	Percent Change from the Baseline	
Pond Area	187,041				
Buffer Area	116,970	Challenger without Buffer Costs	$1,485,166		
Profit / Sq Foot Ranges Combinations	Profit per Sq Ft.	New Outcome of Partial Budget			Sensitivity Index
Upper/ Upper	$0.13	($1,209,226)		0.00%	—
Upper/ Mean	$0.15	($1,207,844)		-0.11%	-0.01
Upper/Lower	$0.18	($1,205,974)		-0.27%	-0.01
Mean/Upper	$0.11	($1,210,428)		0.10%	-0.01
Mean/Mean	$0.13	($1,209,226)		0.00%	—
Mean/Lower	$0.15	($1,207,600)		-0.13%	-0.01
Lower/Upper	$0.10	($1,211,630)		0.20%	-0.01
Lower/Mean	$0.11	($1,210,608)		0.11%	-0.01
Lower/Lower	$0.13	($1,209,226)		0.00%	—

[197] Nursery A did not have a capture pond to measure

Appendix Table 111: Cost of Land Sensitivity Analysis Table Nursery C

Cost of Land Sensitivity Analysis Table					
Nursery C					
Group	5	Defender without Pond Costs	$614,887	Percent Change from the Baseline	Sensitivity Index
Pond Area	874,937				
Buffer Area	66,840	Challenger without Buffer Costs	$1,235,340		
Profit / Sq Foot Ranges Combinations	Profit per Sq Ft.	New Outcome of Partial Budget			
Upper/ Upper	$0.13	($1,129,071)		0.00%	—
Upper/ Mean	$0.15	($1,113,131)		-1.41%	-0.09
Upper/Lower	$0.18	($1,091,565)		-3.32%	-0.09
Mean/Upper	$0.11	($1,142,932)		1.23%	-0.09
Mean/Mean	$0.13	($1,129,071)		0.00%	—
Mean/Lower	$0.15	($1,110,318)		-1.66%	-0.09
Lower/Upper	$0.10	($1,156,794)		2.46%	-0.09
Lower/Mean	$0.11	($1,145,012)		1.41%	-0.09
Lower/Lower	$0.13	($1,129,071)		0.00%	—

Appendix Table 112: Cost of Land Sensitivity Analysis Table Nursery D

Cost of Land Sensitivity Analysis Table					
Nursery D					
Group	5	Defender without Pond Costs	$3,777	Percent Change from the Baseline	Sensitivity Index
Pond Area	4,560				
Buffer Area	37,431	Challenger without Buffer Costs	$5,283		
Profit / Sq Foot Ranges Combinations	Profit per Sq Ft.	New Outcome of Partial Budget			
Upper/ Upper	$0.13	($5,828)		0.00%	—
Upper/ Mean	$0.15	($6,477)		11.12%	0.74
Upper/Lower	$0.18	($7,354)		26.18%	0.74
Mean/Upper	$0.11	($5,264)		-9.67%	0.74
Mean/Mean	$0.13	($5,828)		0.00%	—
Mean/Lower	$0.15	($6,591)		13.09%	0.74
Lower/Upper	$0.10	($4,701)		-19.35%	0.74
Lower/Mean	$0.11	($5,180)		-11.12%	0.74
Lower/Lower	$0.13	($5,828)		0.00%	—

Appendix Table 113: Cost of Land Sensitivity Analysis Table Nursery E

Cost of Land Sensitivity Analysis Table					
Nursery E					
Group	5	Defender without Pond Costs	$120,580	Percent Change from the Baseline	Sensitivity Index
Pond Area	309,694				
Buffer Area	7,421	Challenger without Buffer Costs	$282,697		
Profit / Sq Foot Ranges Combinations	Profit per Sq Ft.	New Outcome of Partial Budget			
Upper/ Upper	$0.13	($122,367)		0.00%	—
Upper/ Mean	$0.15	($116,405)		-4.87%	-0.32
Upper/Lower	$0.18	($108,338)		-11.47%	-0.32
Mean/Upper	$0.11	($127,552)		4.24%	-0.32
Mean/Mean	$0.13	($122,367)		0.00%	—
Mean/Lower	$0.15	($115,352)		-5.73%	-0.32
Lower/Upper	$0.10	($132,737)		8.47%	-0.32
Lower/Mean	$0.11	($128,330)		4.87%	-0.32
Lower/Lower	$0.13	($122,367)		0.00%	—

Appendix Table 114: Cost of Land Sensitivity Analysis Table Nursery F

Cost of Land Sensitivity Analysis Table					
Nursery F					
Group	4	Defender without Pond Costs	$138,577	Percent Change from the Baseline	Sensitivity Index
Pond Area	85,883				
Buffer Area	10,527	Challenger without Buffer Costs	$4,304		
Profit / Sq Foot Ranges Combinations	Profit per Sq Ft.	New Outcome of Partial Budget			
Upper/ Upper	$0.46	$168,750		0.00%	—
Upper/ Mean	$0.53	$173,921		3.06%	0.20
Upper/Lower	$0.62	$180,918		7.21%	0.20
Mean/Upper	$0.06	$139,112		-17.56%	0.20
Mean/Mean	$0.46	$168,750		0.00%	—
Mean/Lower	$0.54	$174,834		3.61%	0.20
Lower/Upper	$0.34	$159,756		-5.33%	0.20
Lower/Mean	$0.39	$163,578		-3.06%	0.20
Lower/Lower	$0.46	$168,750		0.00%	—

Appendix Table 115: Cost of Land Sensitivity Analysis Table Nursery G

Cost of Land Sensitivity Analysis Table					
Nursery G					
Group	5	Defender without Pond Costs	$44,081	Percent Change from the Baseline	Sensitivity Index
Pond Area	84,877				
Buffer Area	7,486	Challenger without Buffer Costs	$54,846		
Profit / Sq Foot Ranges Combinations	Profit per Sq Ft.	New Outcome of Partial Budget			
Upper/ Upper	$0.13	($588)		0.00%	—
Upper/ Mean	$0.15	$939		-259.79%	-17.32
Upper/Lower	$0.18	$3,004		-611.27%	-17.32
Mean/Upper	$0.11	($1,915)		225.91%	-17.32
Mean/Mean	$0.13	($588)		0.00%	—
Mean/Lower	$0.15	$1,208		-305.64%	-17.32
Lower/Upper	$0.10	($3,243)		451.81%	-17.32
Lower/Mean	$0.11	($2,114)		259.79%	-17.32
Lower/Lower	$0.13	($588)		0.00%	—

Appendix Table 116: Cost of Land Sensitivity Analysis Table Nursery H

Cost of Land Sensitivity Analysis Table					
Nursery H					
Group	3	Defender without Pond Costs	$36,070	Percent Change from the Baseline	Sensitivity Index
Pond Area	92,000				
Buffer Area	68,849	Challenger without Buffer Costs	$14,428		
Profit / Sq Foot Ranges Combinations	Profit per Sq Ft.	New Outcome of Partial Budget			
Upper/ Upper	$0.12	$24,322		0.00%	—
Upper/ Mean	$0.13	$24,724		1.65%	0.11
Upper/Lower	$0.16	$25,267		3.89%	0.11
Mean/Upper	$0.10	$23,972		-1.44%	0.11
Mean/Mean	$0.12	$24,322		0.00%	—
Mean/Lower	$0.14	$24,795		1.94%	0.11
Lower/Upper	$0.09	$23,623		-2.87%	0.11
Lower/Mean	$0.10	$23,920		-1.65%	0.11
Lower/Lower	$0.12	$24,322		0.00%	—

Appendix Table 117: Cost of Land Sensitivity Analysis Table Small Synthetic

Cost of Land Sensitivity Analysis Table					
Synthetic Small					
Group	2	Defender without Pond Costs	$10,112	Percent Change from the Baseline	Sensitivity Index
Pond Area	46,382				
Buffer Area	8,583	Challenger without Buffer Costs	$27,844		
Profit / Sq Foot Ranges Combinations	Profit per Sq Ft.	New Outcome of Partial Budget			
Upper/ Upper	$0.07	($20,523)		0.00%	—
Upper/ Mean	$0.08	($20,941)		2.04%	0.14
Upper/Lower	$0.10	($21,508)		4.80%	0.14
Mean/Upper	$0.06	($20,159)		-1.77%	0.14
Mean/Mean	$0.07	($20,523)		0.00%	—
Mean/Lower	$0.09	($21,015)		2.40%	0.14
Lower/Upper	$0.05	($19,795)		-3.55%	0.14
Lower/Mean	$0.06	($20,104)		-2.04%	0.14
Lower/Lower	$0.07	($20,523)		0.00%	—

Appendix Table 118: Cost of Land Sensitivity Analysis Table Large Synthetic

Cost of Land Sensitivity Analysis Table					
Synthetic Large					
Group	5	Defender without Pond Costs	$42,064	Percent Change from the Baseline	Sensitivity Index
Pond Area	383,950				
Buffer Area	36,223	Challenger without Buffer Costs	$278,451		
Profit / Sq Foot Ranges Combinations	Profit per Sq Ft.	New Outcome of Partial Budget			
Upper/ Upper	$0.13	($45,728)		0.00%	—
Upper/ Mean	$0.15	($52,587)		15.00%	1.00
Upper/Lower	$0.18	($61,867)		35.29%	1.00
Mean/Upper	$0.11	($39,763)		-13.04%	1.00
Mean/Mean	$0.13	($45,728)		0.00%	—
Mean/Lower	$0.15	($53,797)		17.65%	1.00
Lower/Upper	$0.10	($33,799)		-26.09%	1.00
Lower/Mean	$0.11	($38,869)		-15.00%	1.00
Lower/Lower	$0.13	($45,728)		0.00%	—

Appendix C: Water and Area Calculations

Appendix Table 119: Proportion Table

Proportion of Current Capacity to the needed Proportion for the Buffer Pond					
Nursery	Capacity (gal)	Uses Per day	Number of Days	Needed Reserves	Proportion of Needed Capacity
A	90,000	12,000	7	84,000	0.933333333
B	11,193,328	1,000,000	7	7,000,000	0.625372527
C	91,629,772	1,000,000	7	7,000,000	0.076394384
D	34,111	40,000	7	280,000	8.208454596
E	16,224,362	55,543	7	388,800	0.023963962
F	5,139,570	90,000	7	630,000	0.122578342
G	3,809,550	48,000	7	336,000	0.088199405
H	688,208	73,575	7	515,025	0.748356775
Ssmall	2,081,752	55,036	7	385,252	0.185061407
Slarge	17,232,881	232,258	7	1,625,806	0.09434325

Appendix Table 120: Water Usages Per Nursery

Water uses per year all together			
Nursery	Water use per month (main season, 7 months)	Water use per month (off season, 5 months, 10% of	Total of Year
A	108,900	10,890	816,750
B	30,000,000	3,000,000	225,000,000
C	12,000,000	1,200,000	90,000,000
D	1,200,000	120,000	9,000,000
E	411,420	41,142	3,085,650
F	2,700,000	270,000	20,250,000
G	2,100,000	210,000	15,750,000
H	304,920	30,492	2,286,900
Ssmall	1,651,080	165,108	12,383,100
Slarge	6,967,740	696,774	52,258,050

Appendix Table 121: Amount of Chlorine Needed Per Nursery

Amount of Chlorine Needed per Nursery given a 2ppm requirement				
PPM water				
Nursery	Water use per year	Water use in 1 million pounds	Lbs. of Chlorine needed for 2ppm	Cost of Chlorine
A	816,750	6.80625	13.6125	$101.55
B	225,000,000	1,875.00000	3750	$27,975.00
C	90,000,000	750.00000	1500	$11,190.00
D	9,000,000	75.00000	150	$1,119.00
E	3,085,650	25.71375	51.4275	$383.65
F	20,250,000	168.75000	337.5	$2,517.75
G	15,750,000	131.25000	262.5	$1,958.25
H	2,286,900	19.05750	38.115	$284.34
Ssmall	12,383,100	103.19250	206.385	$1,539.63
Slarge	52,258,050	435.48375	870.9675	$6,497.42
*150 lbs cylinder for rent costs $1,120.00				
so the cost per pound of a cylinder is $7.46 per pound of chlorine				

Appendix Table 122[198]: Sensitivity Analysis Tables Cost of Water

Future cost of extraction of 1 gallon of water from either a municipal or well water source											
	Model	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Nursery D	ARIMA(0,1,1)	Lower PI				0.00006814	0.00006167	0.00005447	0.00004743	0.00004082	0.00003471
		Predicted				0.00007722	0.00008040	0.00008211	0.00008304	0.00008353	0.00008380
		Upper PI				0.00008630	0.00009914	0.00010975	0.00011864	0.00012624	0.00013289
Nursery F	ARIMA(0,1,1)	Lower PI				0.00006620	0.00005705	0.00005106	0.00004625	0.00004212	0.00003845
		Predicted				0.00007596	0.00007596	0.00007596	0.00007596	0.00007596	0.00007596
		Upper PI				0.00008573	0.00009488	0.00010087	0.00010567	0.00010980	0.00011348
Nursery G	AR(1)	Lower PI				0.00005637	0.00005500	0.00005420	0.00005370	0.00005337	0.00005314
		Predicted				0.00006061	0.00006044	0.00006030	0.00006018	0.00006009	0.00006002
		Upper PI				0.00006485	0.00006588	0.00006639	0.00006667	0.00006682	0.00006690
Nursery A	ARMA(1,1)	Lower PI				0.00349052	0.00302093	0.00287457	0.00282451	0.00280705	0.00280100
		Predicted				0.00535890	0.00536278	0.00536510	0.00536650	0.00536734	0.00536784
		Upper PI				0.00722729	0.00770463	0.00785564	0.00790849	0.00792762	0.00793469
Nursery B	ARMA(1,1)	Lower PI	0.00420074	0.00390580	0.00369285	0.00353144	0.00340582	0.00330635	0.00322661	0.00316206	0.00310940
		Predicted	0.00515190	0.00504358	0.00495058	0.00487073	0.00480218	0.00474333	0.00469280	0.00464942	0.00461218
		Upper PI	0.00610306	0.00618136	0.00620831	0.00621002	0.00619854	0.00618031	0.00615900	0.00613678	0.00611495
Nursery C	ARIMA(1,1,1)	Lower PI	0.00443245	0.00456961	0.00442615	0.00444264	0.00438812	0.00437120	0.00433762	0.00431363	0.00428618
		Predicted	0.00509715	0.00523435	0.00516636	0.00520005	0.00518335	0.00519163	0.00518753	0.00518956	0.00518855
		Upper PI	0.00576185	0.00589909	0.00590656	0.00595746	0.00597858	0.00601206	0.00603743	0.00606549	0.00609092
Nursery E	ARIMA(0,2,1)	Lower PI				0.00346661	0.00368010	0.00386619	0.00402786	0.00416757	0.00428723
		Predicted				0.00361088	0.00397427	0.00433766	0.00470105	0.00506444	0.00542784
		Upper PI				0.00375516	0.00426844	0.00480913	0.00537425	0.00596131	0.00656844
Nursery H	MA(1)	Lower PI					0.00363861	0.00367008	0.00367008	0.00367008	0.00367008
		Predicted					0.00488931	0.00511151	0.00511151	0.00511151	0.00511151
		Upper PI					0.00614000	0.00655294	0.00655294	0.00655294	0.00655294

[198] R code for these out puts can be seen later in Appendix D

Appendix Table 123: Profit per Square Foot for sensitivity analysis of group characteristics

Profit Per Square Foot as Relating to the Sensitivity Analysis of the Characteristics of Each Group (Profit/Sq Ft)			
Group 1 (Revenue Less than $25,000)			
	Square Feet		
Operating Profit	Upper	Mean	Lower
Upper	$0.23	$0.26	$0.31
Mean	$0.20	$0.23	$0.27
Lower	$0.17	$0.19	$0.23
Group 2 (Revenue between $25,001 and $100,00)			
	Square Feet		
Operating Profit	Upper	Mean	Lower
Upper	$0.07	$0.08	$0.10
Mean	$0.06	$0.07	$0.09
Lower	$0.05	$0.06	$0.07
Group 3 (Revenue between $100,001 and $500,000)			
	Square Feet		
Operating Profit	Upper	Mean	Lower
Upper	$0.12	$0.13	$0.16
Mean	$0.10	$0.12	$0.14
Lower	$0.09	$0.10	$0.12
Group 4 (Revenue between $500,001 and $1,000,000)			
	Square Feet		
Operating Profit	Upper	Mean	Lower
Upper	$0.46	$0.53	$0.62
Mean	$0.40	$0.46	$0.54
Lower	$0.34	$0.39	$0.46
Group 5 (Revenue above $1,000,001)			
	Square Feet		
Operating Profit	Upper	Mean	Lower
Upper	$0.13	$0.15	$0.18
Mean	$0.11	$0.13	$0.15
Lower	$0.10	$0.11	$0.13

Appendix Table 124: Descriptive statistics for profit and square foot for each group

The Upper, Mean, and Lower bounds of the sensitivity analysis as it pertains to Profit per Square Foot separated for each Nursery Group					
Profit					
Group	1 (Less than $25,000)	2 (Revenue between $25,001 and $100,000)	3 (Revenue between $100,001 and $500,000)	4 (Revenue between $500,001 and $1,000,000)	5 (Revenue above $1,000,001)
N	24	22	35	16	19
Mean	$ 9,073	$ 35,735	$ 168,815	$ 299,952	$1,744,119
15% of the Mean	$ 1,361	$ 5,360	$ 25,322	$ 44,993	$ 261,618
Upper	$ 10,434	$ 41,095	$ 194,137	$ 344,945	$2,005,736
Lower	$ 7,712	$ 30,375	$ 143,493	$ 254,959	$1,482,501
Square Foot					
Group	1 (Less than $25,000)	2 (Revenue between $25,001 and $100,000)	3 (Revenue between $100,001 and $500,000)	4 (Revenue between $500,001 and $1,000,000)	5 (Revenue above $1,000,001)
N	24	22	35	16	19
Mean	40,040	483,932	1,458,562	655,603	13,262,771
15% of the Mean	6,006	72,590	218,784	98,340	1,989,416
Upper	46,046	556,521	1,677,346	753,944	15,252,187
Lower	34,034	411,342	1,239,778	557,263	11,273,355

Appendix Table 125: Maryland Permits Table[199]

Permit Number	Decryption	Info	Type	Time	Costs	
3.01	Surface Water Discharge Permit (Industrial)	Permit designed to meet National Pollutant Discharge Elimination System. Issued for industrial facilities that discharge state surface water	New Minor Facility New Major Facility Renewal Minor Renewal Facilities	9 Mon 12 Mon 14 Mon Depends on Watershed	Application Fee Annual Permit	$50- $20,000 $100-$5,000 (depending on volume)
3.02	Industrial Waste water/ storm water general permit	Industrial wastewater discharge. Discharge of waste/storm water to any place other than a sanitary sewer.	Concentrated animal feeding operations Storm water associated with industrial activities Other general permits	180 days 60 days 90 days	Application Fee Annual Permit	$0-$5,000 (depending on volume) $0-$5,000 (depending on volume)
3.05	Ground water discharge permit	Permit to control the disposal of treated municipal or industrial wastewater into the states' ground water via spray irrigation and other land-treatment application as well as into subsurface by a drain field or seepage	New Minor Facility Renewal minor Facilities	9 Mon 14 Mon Approval lasts max. of 5 Years	Application Fee Annual Permit Municipal Permits	$50- $20,000 $100-$5,000 (depending on volume) No Fee
3.07	Water and Sewerage Construction Permit	To make a large projects sound with engendering principles (must get a discharge purpose before getting the construction permit) differences between major and minor sewerage facilities	Water mains and gravity sewers Water and wastewater pumping stations water treatment plants Wastewater treatment plants			$125-$1800 $400-$1400 $250-$2000 $450-$2000 (All prices dependent on the size and distances of mains)
3.14	Well Construction Permit	Have programs that appropriate underground water and protect aquifers for future uses. Information pertaining to geological structure is also needed	Well Approval	30 days Approval will last twelve months		May not exceed $160 Each county may establish the fee though
3.15	Water Appropriation and Use Permit	Permit required for any activity that withdraws water from the state's surface and or underground waters unless exempted below	Under 10,000 gallons per day 10,000 gallons per day or more	90 days 18 months Approval lasts max. twelve years		No Fee Approvals are subject to review every 3 years Withdrawal much be begun 2 years after approval
3.18	Tidal Wetlands Licenses and Permits	Tidal wetlands program is to manage tidal wetlands to provide reasonable use while furnishing essential resource protection	Minor projects Major projects	5 Mon 10 Mon Approval for Max. 3 Yrs.	No fee for Minor $250-$1000	Fees at www.mde.state.md.us/assets/documents/wetlands_application_fee.pdf
3.19	Noontide wetlands (noontide wetlands and waterways permits)	Manage noontide wetlands and waterways program is to manage noontide wetlands and to provide essential resource protection by authorizing only necessary and unavoidable	Minor Projects Major Projects	10 Mon 12 Mon		Fees at www.mde.state.md.us/assets/documents/wetlands_application_fee.pdf
3.20	Waterway and 100-year Floodplain (noontide wetlands and waterways)	Waterway construction regulations assure that activates in a waterway or its floodplain do not create flooding on upstream or downstream of property	Minor Projects Major Projects	10 Mon 12 Mon		Fees at www.mde.state.md.us/assets/documents/wetlands_application_fee.pdf
3.21	Erosion/Sediment Control and Storm water Management	Erosion/sediment control plan approval is required before construction to prevent siltation due to releases of sediment soil from active construction sites.	Erosion/ sediment control approval Storm water Management Plan approval Both Private and Gov't plans sent to local officials	2 Years No Expiration	None None	
3.23	General Permit for Storm water Associated with Construction Activity	Required for all construction activity in Maryland with a planned total disturbance of one acre or more	1 to less than 10 Acres disturbed 10 to less than 15 Acres disturbed 15 to less than 20 Acres disturbed 20 or more Acres		$100 $500 $1,500 $2,500	
3.28	Well Driller License		New Licenses Initial Licenses Fee Renewal Licenses	6 Mon 6 Mon 30 days	App Fee $150 $100-$300 $200-$400	

199 (The Maryland Department of the Environment, 2014)

Appendix Table 126: Water Meter Schedule from City of Washington D.C.

Table 2 Cold-Water Meters - Displacement Type, Bronze Main Case

Meter Size	Low Flow Registration	Normal Operating Range	Recommended Max Rate for Continuous Operations	Safe Max Operating Capacity
1-inch	3/4 gpm	3-50 gpm	25 gpm	50 gpm
1 1/2 inch	1 1/2 gpm	5-100 gpm	50 gpm	100 gpm
2-inch	2 gpm	8-160 gpm	80 gpm	160 gpm

Table 3 Cold-Water Meters - Turbine Type, for Customer Service

Meter Size	Low Flow Registration	Normal Operating Range	Recommended Max Rate for Continuous Operations	Safe Max Operating Capacity
3-inch	-	8-435 gpm	350 gpm	435 gpm
4-inch	-	15-750 gpm	650 gpm	750 gpm
6-inch	-	30-1,600 gpm	1,400 gpm	1,600 gpm
8-inch	-	50-2,800 gpm	2,400 gpm	2,800 gpm
10-inch	-	75-4,200 gpm	3,500 gpm	4,200 gpm
12-inch	-	120-5,300 gpm	4,400 gpm	5,300 gpm

Table 4 Fire Service Lateral Velocity Check

Fire Service Lateral Diameter (in)	Fire Service Lateral Area (sf)	Flow Rate thru Fire Lateral* (gpm)	Flow Rate thru Fire Lateral (cfs)	V (fps) = Q (cfs)/A (sf)
2" diameter	0.02	350	0.77	35.17
3" diameter	0.05	350	0.77	15.69
4" diameter	0.09	350	0.77	8.85
6" diameter	0.20	350	0.77	3.92
8" diameter	0.35	350	0.77	2.20
10" diameter	0.54	350	0.77	1.41
12" diameter	0.79	350	0.77	0.98

*If NO fire pump is required - enter the actual fire flow demand per NFPA

Appendix D: R-Code

The R-Code was used to predict future prices of water extraction as it relates to the cost of electricity and the cost of muniipal water. Predictions were made into the future up to the year 2019, and were based on data of prices back as far as 2000 in some instances. These predictions were used for the sensitivity analysis of water in the partial budgets.

R Code [200]:

```
setwd("~/LISA_spring2014/Nate")
data<-read.csv("water_price.csv")
head(data)

#D
ts1<-ts(data[complete.cases(data[,2]),2],start=2001,freq=1)
#F
ts2<-ts(data[complete.cases(data[,3]),3],start=2001,freq=1)
#G
ts3<-ts(data[complete.cases(data[,4]),4],start=2001,freq=1)

par(mfrow=c(1,3))
plot(ts1,main="D")
plot(ts2,main="F")
plot(ts3,main="G")

#A
ts4<-ts(data[2:15,5],start=2000,freq=1)
#B
ts5<-ts(data[2:12,6],start=2000,freq=1)
#C
ts6<-ts(data[2:12,7],start=2000,freq=1)
#E
ts7<-ts(data[1:15,8],start=1999,freq=1)
#H
ts8<-ts(data[8:16,9],start=2006,freq=1)

par(mfrow=c(1,5))
plot(ts4,main="A")
plot(ts5,main="B")
plot(ts6,main="E")
plot(ts7,main="C")
plot(ts8,main="H")

plot(diff(ts1,1))

plot(ts2)
plot(diff(ts2,1))

plot(ts3)
```

[200] (Song & Zhang, 2015)

```
plot(diff(ts3,1))

#Autocorrelation plot
#ts1
plot(ts1)
plot(diff(ts1,1))
plot(acf(diff(ts1,1)))
plot(pacf(diff(ts1,1)))
fit.ts1<-arima(ts1,c(1,1,1))
fit.ts1_ar<-arima(ts1,c(1,1,0))
fit.ts1_ma<-arima(ts1,c(0,1,1))

tsdiag(fit.ts1)
tsdiag(fit.ts1_ar)
tsdiag(fit.ts1_ma)

pred.ts1<-predict(fit.ts1,n.ahead=6)
pred.ts1
plot(c(2001:2019),c(ts1,pred.ts1$pred),type="l",ylim=c(0,0.0002))
lines(pred.ts1$pred,col="red")
lines(pred.ts1$pred+2*pred.ts1$se,col="red",lty=3)
lines(pred.ts1$pred-2*pred.ts1$se,col="red",lty=3)


#TS2
plot(ts2)
plot(diff(ts2,1))
plot(acf(diff(ts2,1)))
plot(pacf(diff(ts2,1)))
fit.ts2<-arima(ts1,c(0,1,1))
tsdiag(fit.ts2)
pred.ts2<-predict(fit.ts2,n.ahead=6)
plot(c(2001:2019),c(ts2,pred.ts2$pred),type="l",ylim=c(0,0.0002))
lines(pred.ts2$pred,col="red")
lines(pred.ts2$pred+2*pred.ts2$se,col="red",lty=3)
lines(pred.ts2$pred-2*pred.ts2$se,col="red",lty=3)


#TS3
plot(ts3)
plot(acf(ts3))
plot(pacf(ts3))
plot(diff(ts3,1))
plot(acf(diff(ts3,1)))
plot(pacf(diff(ts3,1)))
fit.ts3<-arima(ts3,c(1,0,0))
tsdiag(fit.ts3)
pred.ts3<-predict(fit.ts3,n.ahead=6)
plot(c(2001:2019),c(ts3,pred.ts3$pred),type="l",ylim=c(0,0.0002))
lines(pred.ts3$pred,col="red")
lines(pred.ts3$pred+2*pred.ts3$se,col="red",lty=3)
lines(pred.ts3$pred-2*pred.ts3$se,col="red",lty=3)
```

```
#TS4
plot(ts4,ylim=c(0,0.01))
plot(acf(ts4))
plot(pacf(ts4))
plot(diff(ts4,1))
plot(acf(diff(ts4,1)))
plot(pacf(diff(ts4,1)))
fit.ts4<-arima(ts4,c(1,0,1))
tsdiag(fit.ts4)
pred.ts4<-predict(fit.ts4,n.ahead=6)
plot(c(2000:2019),c(ts4,pred.ts4$pred),type="l",ylim=c(0,0.02))
lines(pred.ts4$pred,col="red")
lines(pred.ts4$pred+2*pred.ts4$se,col="red",lty=3)
lines(pred.ts4$pred-2*pred.ts4$se,col="red",lty=3)


#TS5
plot(ts5,ylim=c(0,0.01))
plot(acf(ts5))
plot(pacf(ts5))
plot(diff(ts5,1))
plot(acf(diff(ts5,1)))
plot(pacf(diff(ts5,1)))
fit.ts5<-arima(ts5,c(1,0,1))
tsdiag(fit.ts5)
pred.ts5<-predict(fit.ts5,n.ahead=9)
plot(c(2000:2019),c(ts5,pred.ts5$pred),type="l",ylim=c(0,0.02))
lines(pred.ts5$pred,col="red")
lines(pred.ts5$pred+2*pred.ts5$se,col="red",lty=3)
lines(pred.ts5$pred-2*pred.ts5$se,col="red",lty=3)


#TS6
plot(ts6,ylim=c(0,0.01))
plot(acf(ts6))
plot(pacf(ts6))
plot(diff(ts6,1))
plot(acf(diff(ts6,1)))
plot(pacf(diff(ts6,1)))
fit.ts6<-arima(ts6,c(1,1,1))
tsdiag(fit.ts6)
pred.ts6<-predict(fit.ts6,n.ahead=9)
plot(c(2000:2019),c(ts6,pred.ts6$pred),type="l",ylim=c(0,0.02))
lines(pred.ts6$pred,col="red")
lines(pred.ts6$pred+2*pred.ts6$se,col="red",lty=3)
lines(pred.ts6$pred-2*pred.ts6$se,col="red",lty=3)

plot(ts7,ylim=c(0,0.01))
plot(acf(ts7))
plot(pacf(ts7))
```

```
plot(diff(ts7,2))
plot(acf(diff(ts7,2)))
plot(pacf(diff(ts7,2)))
fit.ts7<-arima(ts7,c(0,2,1))
tsdiag(fit.ts7)
pred.ts7<-predict(fit.ts7,n.ahead=6)
plot(c(1999:2019),c(ts7,pred.ts7$pred),type="l",ylim=c(0,0.02))
lines(pred.ts7$pred,col="red")
lines(pred.ts7$pred+2*pred.ts7$se,col="red",lty=3)
lines(pred.ts7$pred-2*pred.ts7$se,col="red",lty=3)


plot(ts8,ylim=c(0,0.01))
plot(acf(ts8))
plot(pacf(ts8))
plot(diff(ts8,1))
plot(acf(diff(ts8,2)))
plot(pacf(diff(ts8,2)))
fit.ts8<-arima(ts8,c(0,0,1))
tsdiag(fit.ts8)
pred.ts8<-predict(fit.ts8,n.ahead=5)
plot(c(2006:2019),c(ts8,pred.ts8$pred),type="l",ylim=c(0,0.02))
lines(pred.ts8$pred,col="red")
lines(pred.ts8$pred+2*pred.ts8$se,col="red",lty=3)
lines(pred.ts8$pred-2*pred.ts8$se,col="red",lty=3)
```

Appendix E: IRB Consent Form

Informed Consent for Participants
in Research Projects Involving Human Subjects

Title of Project: Managing Water-borne Diseases in Horticultural Operations

Investigators: Dr. Darrell Bosch, Dr. James Pease, Dr. Kevin Boyle, and Dr. Chuan Hong

I. Purpose of this Research/Project
The project seeks to understand constraints and opportunities for your adoption of strategies to manage waterborne diseases in horticultural grower operation. The interview will collect data on your irrigation system, its investment and operating costs, and practices and costs regarding waterborne disease management. The information will be used to create a synthetic but representative "model nursery" that disseminates non-firm-specific information about the components and costs of nursery irrigation recycling systems.

II. Procedures
Personal interview surveys are held at your business operation or another location convenient to your operation and will last approximately one and one-half hours.

III. Risks
The personal interview survey has no potential risks to you. Your anonymity will be protected. The case studies will not identify your business.

IV. Benefits
Other ornamental nursery producers will learn improved information to better manage disease that reduce crop losses and improve crop quality.

V. Extent of Anonymity and Confidentiality
Interview results will be published anonymously so that no reader can associate your business with the information.

VI. Compensation
There is no monetary compensation offered for participation.

VII. Freedom to Withdraw
You are free to withdraw from the personal interview at any time.

VIII. Subject's Responsibilities

I voluntarily agree to participate in this study. I have the following responsibilities: participate in the personal interview to provide irrigation system and disease management information from my nursery. .

IX. Subject's Permission

I have read the Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

____ Date__________

Subject signature

Should I have any pertinent questions about this research or its conduct, and research subjects' rights, and whom to contact in the event of a research-related injury to the subject, I may contact:

Dr. James Pease Investigator	540-231-4178/peasej@vt.edu Telephone/e-mail
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